Food and Agriculture Organization
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Exploring the impact of alternative population projections on prices, growth and poverty developments

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Commodity markets, economic growth and development

Exploring the impact of alternative population projections on prices, growth and poverty developments

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Acronyms

CAP	Common Agricultural Policy
CES	Constant Elasticity of Substitution
CGE	Computable General Equilibrium
FAOSTAT	The Food and Agriculture Organization Corporate Statistical Database
GDP	Gross Domestic Product
GTAP	Global Trade Analysis Project
IEA	International Energy Agency
IFPRI	International Food Policy Research Institute
IIASA	International Institute for Applied Systems Analysis
IMAGE	Integrated Model to Assess the Greenhouse Effect
MAGNET	Modular Applied GeNeral Equilibrium Tool
NAFTA	North American Free Trade Agreement
SAM	Social Accounting Matrix
SSP2	Shared Socioeconomic Pathway 2
UN	United Nations

Abstract

This study aims at exploring the implications for future economic growth and poverty of different agricultural price trajectories through scenario analysis. Agricultural prices are not a given but the end result of underlying changes in demand and supply. Acknowledging that the future is uncertain we assess the implications of contrasting developments in population, a key driver of agricultural prices, through its impact on demand.

Using MAGNET, a global computable general equilibrium (CGE) model we develop three scenarios. The reference or baseline scenario is built upon the "Middle of the road" Shared Socioeconomic Pathway (SSP2), projecting from 2010 to 2030 with no major divergence from historical patterns. We then construct alternative high and low price scenarios by varying assumptions on population growth. The aim is not to predict the future but to systematically think through how different paths of a key driver changes how the world may look. Any model covering the entire world economy uses a large number of assumptions with varying levels of empirical support. We therefore also highlight key assumptions which need more empirical scrutiny to improve our understanding of the likely direction of future development

I. Background and context

Agriculture keeps grabbing the attention of policy–makers, even in high income countries where it accounts for only a minor share of GDP. This persistent interest results from agriculture's many roles. Like other sectors it needs to provide an income for its producers, but the food it produces and the way these are produced attract more interest than non–agricultural production. A growing world population implies that more food needs to be produced; there is no substituting away from the basic human need to eat. And with rising incomes in the developing world the type of food demanded by this growing population shifts towards animal protein, putting even more pressure on the agricultural system. Expanding the agricultural area has been an important source of production increase in the past, making it a key driver of losses in habitat and biodiversity. Agricultural production is also affected by, and influences through emission and land conversion, the other key current global challenge – climate change (von Lampe, 2015). Finally, agriculture remains a key source of income for many of the world's poor, either directly as farmers or by working as agricultural labourer (Hertel *et al.*, 2016). Where and how the world's food is produced thus has implications for the extent to which the required global increase in food production benefits the poor and supports or threatens sustainability objectives.

This paper uses MAGNET, a global computable general equilibrium (CGE) model, to simulate the possible effects of population growth (a key demand driver) on food prices trajectories to 2030. Starting from a baseline scenario built upon the Shared Socioeconomic Pathway (SSP2), projections are made from 2010 to 2030 providing alternative high and low price scenarios.

We start by a short review of the literature on the link between agricultural prices, economic growth and poverty which centres around the question whether high food prices are good or bad. We then introduce the model and describe the three scenarios. The main part of this report revolves around macro level implications looking at agricultural prices, agricultural production and regional patterns in economic growth. Since understanding the poverty implications requires an understanding of the distribution of costs and benefits, we then take a closer look at the results for representative households. The final chapter concludes.

II. The link between agricultural prices and poverty

For most commodities the link between prices and development is straightforward: low prices harm producers and benefit buyers (and vice versa). The recent collapse in oil prices made newspaper headlines since it harmed the newly developed (high–cost) shale oil production in the Northern America and important global players like Russia depending on oil exports (Krauss, 2016). At the same time the low oil prices spurs global economic growth by lowering the costs of the global fossil–fuel based production system, as well as directly benefitting consumers who pay less at the gas station.

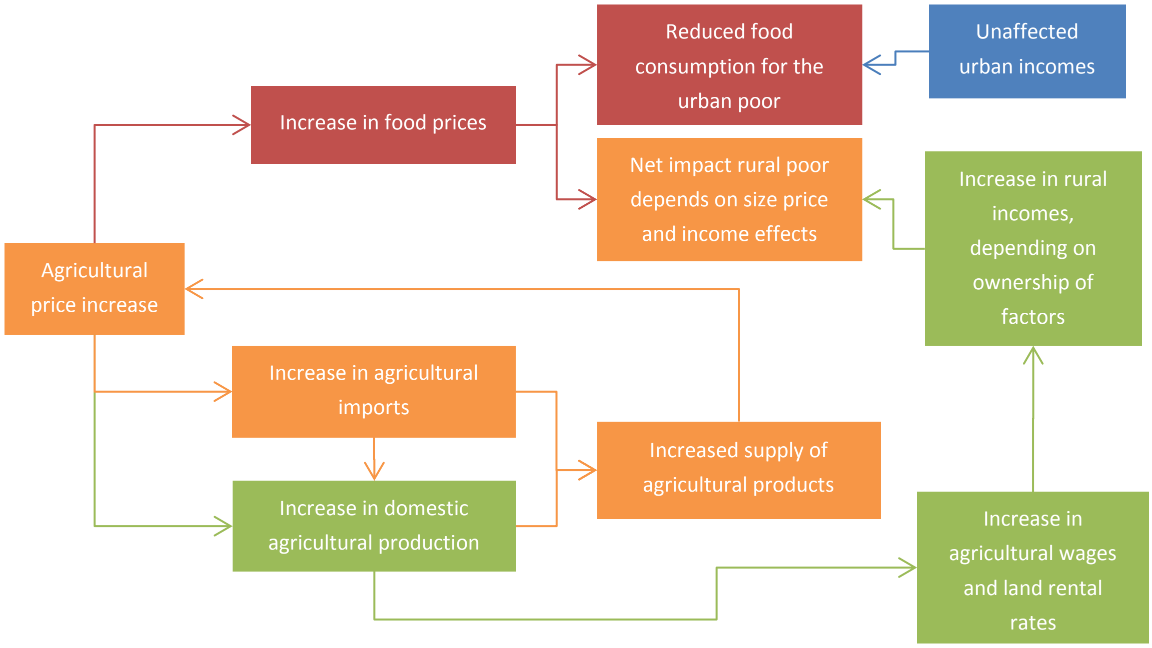
In the case of agricultural prices the net effect of a high (low) price is not a clear cut, leading to an extensive literature on the link between agricultural prices and economic development. Agricultural production does not respond to different economic laws, but it has strong income effects on the rural poor which turn agricultural prices increases into a double–edged sword. Essentially there is a trade–off between the short–run negative impact of a high price on the ability of the poor to buy food (price effect), and the longer term positive impact of agricultural employment opportunities benefitting the rural poor (income effect) (Timmer, 1983).

For food producers and consumers it is not the economic literature but the actual policies of governments and international agencies which matter. Interestingly, the international consensus on whether the price or income effect of agricultural prices is most important reversed during the recent food price spikes. Before the spikes the income effect was seen as dominant, treating low agricultural prices as problematic. After the food price spikes the price effect took centre stage and high agricultural prices are now seen as threatening food security (Swinnen *et al.*, 2011). This shift in perspective can be linked to mass media coverage of urban protests against the 2007/08 food price spike putting food security and agricultural development high on political and funding agendas (Guariso *et al.*, 2014).

Bellemare (2015) shows that rising food prices contribute to food riots, while such a relationship cannot be established for food price volatility. It is not surprising that these riots are more likely in areas with a concentration of poor households – being the most affected since food expenditures take a larger share of low incomes. Food prices are thus important for political stability which on its turn is conducive for economic growth. Rising food prices will also disproportionally hit poor households and may cause an increase in malnutrition affecting labour productivity and perpetuating poverty. Concluding that high food prices are bad for the poor, however, ignores the income effects of higher food prices which can dampen or even reverse the impacts.

Figure 1 summarizes key mechanisms through which agricultural prices affect growth and poverty. The immediate impact of an increase in agricultural prices is an increase in food prices (the price effect). This harms the poor disproportionally since they spend a large share of their income on food. Households may of course substitute between food commodities based on relative price changes, but cannot substitute away from food consumption. In the medium to long term agricultural production will increase, increasing demand for factors like land and labour. This will increase wages and thus rural incomes, where the impact on specific household types depends on their ownership of factors. This income effect may outstrip the price effect, in which case the price increase benefits the poor. For urban households with no income from agriculture only the price effect is relevant, unless the increased demand for agricultural labour increases wages economy–wide. The increase in prices will also induce more imports which benefits foreign agricultural sectors and dampen the domestic price increase (as does the increased domestic agricultural supply).

Figure 1. Schematic overview of the impact of higher agricultural prices on the poor



Source: Authors' elaboration.

The way the agricultural price changes turn out in terms of food access for the poor thus depends on a multitude of factors:

- ability of the agricultural sector to respond to price incentives (availability of production factors, inputs, transmission of prices);
- change in imports (shifts the benefits of increased production to other countries);
- distribution of factor ownership (landless versus land owning households, urban versus rural households);
- distribution of the poor over rural and urban areas;
- labour market segmentation;
- change in rural and urban wages.

Whether or not agricultural prices ought to be high or low to help the poor then depends on perspective, both temporally and spatially. In the short run high food prices harm all poor who may not be able to meet their nutritional needs. In the medium to long term it may benefit the rural poor by increasing their incomes. The opposing effects of the price and income effects makes the net impact of price increases ambiguous and requires a shift in perspective from prices and production to a more complete empirical assessment accounting for both incomes and consumption (Hertel, 2016).

Econometric studies of the impact of higher food prices tend to focus on the first order price impact using Deaton's net benefit ratio model (Deaton, 1989). This partial equilibrium model ignores adjustments in factor markets. As a result these studies conclude that net producers of food gain from higher prices while net consumers loose (Ivanic *et al.*, 2012; de Hoyos and Medvedev, 2011).

A recent econometric study for rural India takes the econometric analyses further, accounting for the possibility of factor market adjustments to higher prices through a simple general equilibrium framework (Jacoby, 2016). The results contradict the partial equilibrium conclusions, finding all rural households gaining from higher food prices. Proportionally the poorest and richest households gain least. These results for India fit with the findings of a study for 31 developing countries using a combination of a global CGE model with micro–level household models that account for changes in both production and consumption (Ivanic and Martin, 2014). The use of simulation models allows decomposition of short run price effect from the medium to long run income effects. The short run price effect is negative, similar to the partial equilibrium models. In the longer term unskilled workers benefit from higher wages while farm households benefit from larger farm profits. At the global level poverty declines with increasing food prices, in line with the findings for rural India. Despite the overall benefits of higher food prices, the impact varies across countries and across the commodities for which price increases are simulated. For example price increases for the staple crops wheat and rice have strong negative short run impacts. A study linking a CGE simulation of food price increases due to biofuels with household survey data to account for the second order effects found smaller but still increasing poverty (de Hoyos and Medvedev, 2011). The latter model did not account for household level changes in production decisions as in the study by Ivanic and Martin, but does point to diversity in impact depending on the source of the food price increase.

The general equilibrium results are supported by a cross–country estimation of the link between food prices and poverty, finding higher prices associated with reductions in poverty (Headey, 2014). There is strong evidence that in periods of 1 to 5 years higher food prices reduce both poverty and inequality. Support measures are still needed to make sure poor households initially hit by higher food prices make it to the long run benefits of higher wages and agricultural returns. These support measures, however, should not prevent the increase in food prices else the long run benefits through the income effect cannot be reaped.

The recent shift in policy–perspective seeing high agricultural prices as bad does not align with the empirical evidence which actually supports the old view of high agricultural prices reducing poverty and food insecurity. Fortunately, despite the urban bias in media coverage and consequences of high food prices, new investments are made to increase agricultural production and reduce rural poverty (Guariso *et al.*, 2014). Poor rural households, which still comprise the majority of the poor, thus benefit both from the higher prices and increased attention for agricultural development.

III. Methodology

National policies almost by definition have an economy–wide impact, aiming at shifting a national economy towards a more desirable point. This will result in economy–wide adjustments, the net effect of which cannot be analytically derived. CGE models are simulation models, designed to quantitatively trace such direct and indirect economy–wide adjustments. MAGNET[1] is a global CGE model based in the GTAP standard model (Hertel, 1997) with a modular set–up allowing us to include more detail or specific extensions where needed (Woltjer *et al.*, 2014). Like other GTAP–based CGE models MAGNET covers the global economy, tracing all economic transactions captured by national statistics[2].

a. The MAGNET model

MAGNET traces domestic links between sectors, through use of output from other sectors (intermediate demand), competition for agricultural land (which can expand, possibly at the cost of deforestation), labour or capital (factor markets, segmented for agricultural and non–agricultural use in the case of labour) and by substituting commodities in the consumption of private households or government (final demand). Intermediate and final demand are linked to developments in other countries through bilateral international trade. Available policy instruments are a range of taxes or subsidies (with government budget implications), imposing production quota or setting mandates on biofuel use.

Production structures can be made sector–specific in MAGNET. The current studies use six different nested CES production structures capturing key substitution possibilities. For example, crop production can substitute different types of fertilizers with land, while the petrol sector is characterized by blending of biofuels with fossil based petrol[3].

MAGNET includes a land supply curve which specifies the relationship between land supply and a land rental rate in each region (van Meijl *et al.*, 2006; Eickhout *et al.*, 2009). Land supply to agriculture can be adjusted by idling agricultural land, converting non–agricultural land to agriculture, converting agricultural land to urban use, protection of forest areas, and agricultural land abandonment. The general idea is that as long as there is enough land available for agriculture the land price will increase modestly but if land becomes scarce its price increases rapidly.

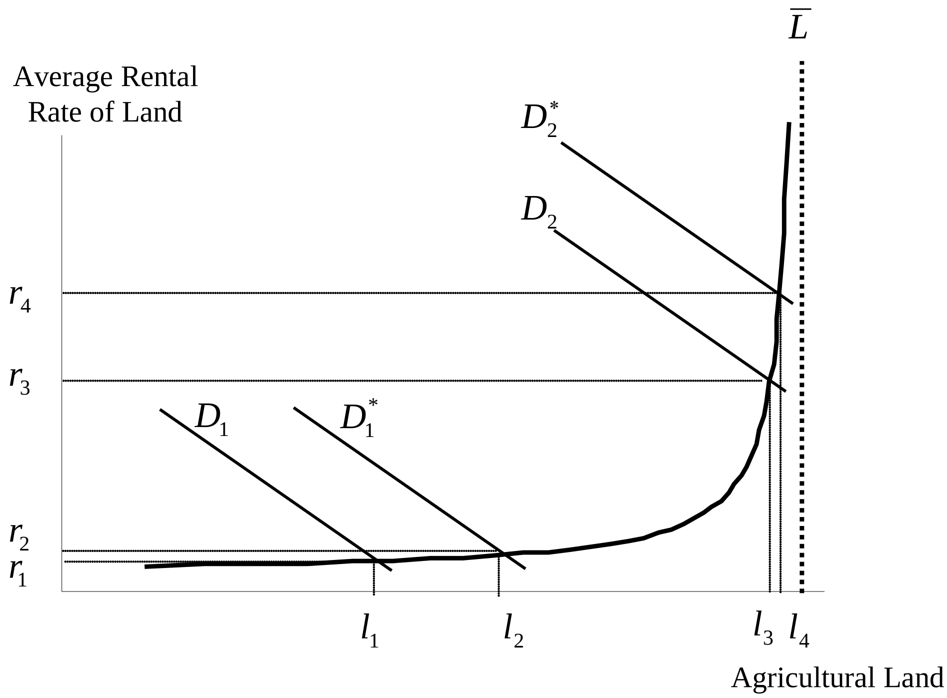
Figure 2 visualizes the idea behind the land supply curve. When agricultural land use approaches potential land use ($\bar{L}$), farmers are forced to use less productive land with higher production costs (strongly increasing part of the supply curve). As a consequence, in land–abundant regions like South America and for members of NAFTA, an increase in demand from D1 to D1* (left–hand side of Figure 2) results in a large

[1] This study is done with the MAGNET – HHS_BIOF branch, revision 5705.
[2] Being derived from national statistics, the GTAP databases excludes economic activities not registered by statistical offices. Activities in the informal economy or farm production directly consumed by farm households may thus not be accounted for.
[3] ANNEX B describes the production structures and key elasticities.

increase in land use (from l_1 to l_2) and a modest increase in rental rates (from r_1 to r_2), while land scarce regions like Japan, Korea, Uganda and Europe experience a small increase in land use and a large increase in the rental rate (right–hand side of Figure 2; shift from D_2 to D_2*). These land price differences will influence food prices and competitiveness of regions.

Sectoral shifts may alter the returns to different types of factors, e.g. increase the value of land through an increased demand for agricultural products. This may result in an expansion of agricultural land and alter the relative income of household groups. For selected countries (Ghana, Kenya and Uganda, India, Indonesia and China) MAGNET includes different household types as well as a finer distinction of factor endowments (Kuiper and Shutes, 2014). The latter allows us to better capture the link between specific sectors and factor incomes, tracing differential income developments of household types.

Figure 2. Impact of increased land demand on land markets



Source: Authors' elaboration.

As the starting point for quantifying the global economy MAGNET uses the GTAP V9 database with 2007 as the reference year (Narayanan *et al.*, 2015). The GTAP database contains detailed bilateral trade, transport and protection data (import tariffs, export subsidies and subsidies to agricultural outputs, inputs and factor payments) characterizing economic linkages among regions, together with detailed country input–output databases accounting for domestic inter–sectoral linkages. The GTAP database is combined with other databases providing the necessary detail for the modular extensions, like FAOSTAT to model land supply and trace agricultural production in quantity terms and the International Energy Agency (IEA) data to distinguish biofuel sectors.

To add household and factor details for selected countries we use national level Social Accounting Matrices (SAMs) distinguishing at least two types of households available through IFPRI[4]. These same databases are used to split standard GTAP factors (land, skilled and unskilled labour) into more detailed factors, data permitting. Using national databases implies that the level of detail, both for households and factors, varies across countries.

b. Scenarios

This study explores the implications of positive and negative deviations of prices from their baseline development for economic growth, poverty and inequality. To this end, three scenarios are run with MAGNET: a baseline or reference scenario (Shared Socioeconomic Pathway 2, SSP2) and two alternative scenarios yielding either high or low agri–food prices. We run a two–step simulation from 2010–2020 and 2020–2030. This allows us to capture current policies set till 2020 (like biofuel mandates) and introduce policy changes in the 2020–2030 period. Table 1 below summarizes the set–up of the experiments. Many of the drivers are country or region specific, as discussed below for population and GDP.

Table 1. Summary of scenario features

	Low population growth	*SSP2 baseline*	*High population growth*
Shared	Technical progress in line with SSP2 GDP developments (aknreg) Capital endowments grow in line with macro shocks (GDP shocks) SSP2 feed efficiency change (afall1) Fossil fuel prices according to 4DS scenario Removal of milk and sugar quota Reduction in first pillar budget CAP		
Specific	• UN low population growth	• SSP2 population growth	• UN high population growth

Source: Authors' elaboration.

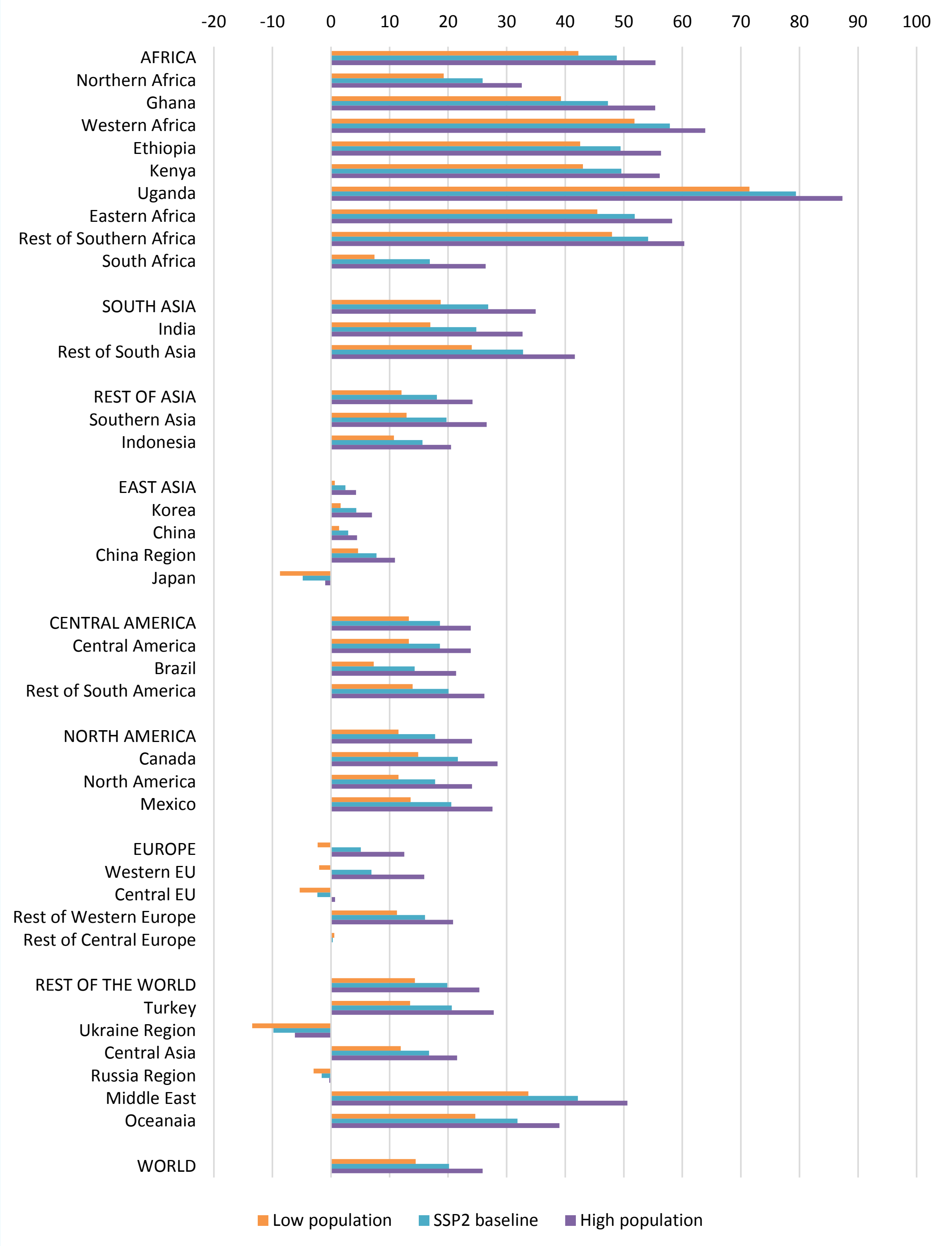
The reference or Baseline scenario in this study is a baseline build on the "Middle of the road". Shared Socioeconomic Pathway (SSP2) projecting from 2010 to 2030. SSP2 assumes no major divergence from the historical patterns. Emerging economies slow when higher level of incomes are reached, there are no major changes in technology and although fossil fuel dependency does decline, no major global shifts in energy use are projected (O'Neill *et al.,* 2016). The moderate GDP and population projections associated with this scenario are taken from the SSP database at IIASA (IIASA, 2015). Expected developments in the yields of crops and livestock are taken from FAO projections (Alexandratos and Bruinsma, 2012). Developments in the prices of crude oil, gas and coal are taken from the 4 degrees (4DS) framework assumptions of the 2015 Energy Technology perspectives study by the IEA (IEA, 2015). Land supply is reduced due to protection of vulnerable areas with data taken from the IMAGE model projections for SSP2. Apart from these main drivers we also account for currently established policies relevant for the development of primary agricultural prices: changes in the European Union's Common Agricultural Policy (CAP) and global first generation biofuel mandates. For the CAP reform we account for a reduction in export subsidies for sugar and raw milk, abolition of production quota and a reduction in first pillar budgets. Biofuel mandates are taken from the *Renewables Global Status Report 2015* (REN21, 2015) and *Biofuel Mandates Around the World: 2015* (Lane, 2015).

[4] ANNEX A describes the aggregation used in this study.

Changes in population provide an important demand side shift in the model. We explore alternative assumption on population growth using two scenarios. The low population scenario adjusts population projections downward using the low country–specific population projections from the UN (United Nations, 2013). The reduced demand for commodities, including fossil fuels, will lower the projected agricultural prices. In contrast, the high price scenario adjusts population projections upward using country–specific alternative population projections which are computed from the UN high population projections (United Nations, 2013). The rise in demand pushes prices up, creating a scenario with high prices.

The difference between the high and low UN population projections vary by region (Figure 3). For readability we present results by major regions throughout the report. More detailed country level results are available from the model (see ANNEX A for a complete description of the model aggregation). Figure 2 includes both the reporting regions and countries included in each reporting region. In most reporting regions the constituting countries show a similar pattern although with at times rather different growth rates. In the African region, for example, Uganda has in the baseline three times the population growth of North Africa (79 versus 26 percent). The European and Rest of the World regions include countries with increasing and declining populations, leading to a weaker regional response. Projections for the total world population vary from 14 percent increase in the low population scenario, to 20 percent in the baseline and 26 percent in the high population scenario. This amounts to an estimated world population varying from 7.9, to 8.3 and 8.7 billion by 2030.

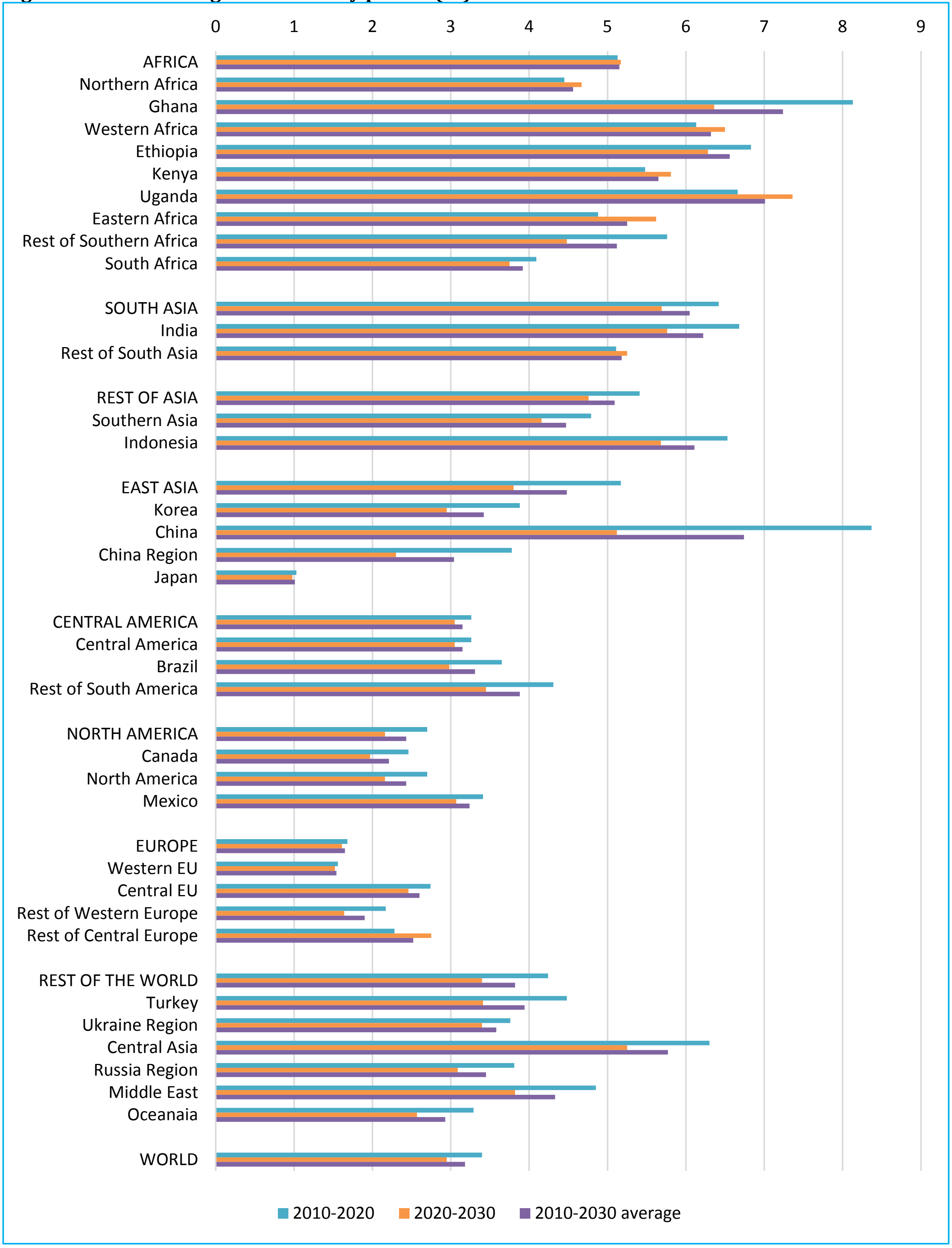
Figure 3. Population growth (2010–2030) by region and scenario (%)



Source: Authors' elaboration.

A second key driver of the model results is the exogenously projected GDP in the baseline. Combined with the population growth this is a key driver of labour productivity, with the latter treated as a Solow residual calibrated to reach the projected GDP. Figure 4 shows the annual growth rate of GDP for each of the simulation periods (2010–2020 and 2020–2030) and the average growth over the period as a whole (2010–2030). For simplicity all reporting is done for the entire simulation at once, averaging the impact of the two periods.

Figure 4. Annual GDP growth rates by period (%)



Source: Authors' elaboration.

The projected GDP growth rates are based on assumptions of convergence, i.e. growth slows with rising GDP. In general this results in higher growth rates for the 2010–2020 period, most notably so for China. The only exceptions are Rest of Central Europe and several African countries. In all these cases the changes in growth rates from the first to the second period are modest. For the African region as a whole a more or less stable annual growth rate results, for most other regions there is a clearer difference in growth rates between the two periods.

IV. Macro level results

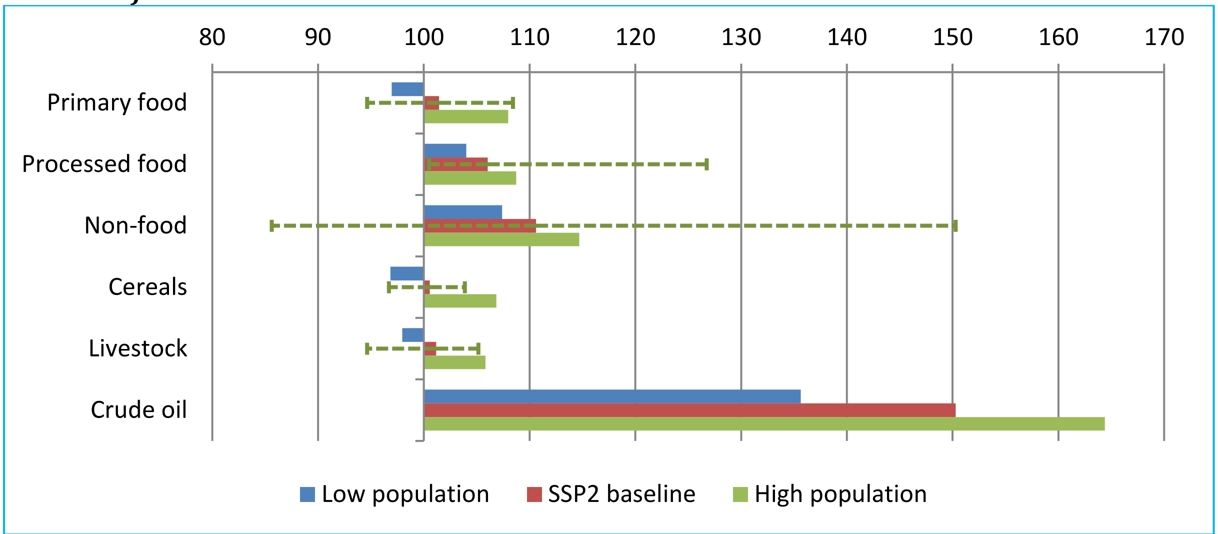
This study focuses on the growth and poverty impacts of agricultural commodity price developments. The scenario set–up has been geared towards generating higher and lower agricultural prices relative to the baseline by using alternative assumptions on population. We therefore start exploring the resulting price developments and decomposing the contribution of the alternative assumptions. We then turn to the implications of these different developments for production, economic growth and incomes.

a. Output price changes

i. Global output price developments

Figure 5 presents the world output price by scenario (computed as the sum of regional export prices weighed by domestic production). The scenarios are ordered such that prices a priori are expected to increase from top to bottom. The first three entries are aggregated prices for food (distinguishing primary and processed food) and non–food commodities. The lower halve presents results for key primary agricultural commodities (cereals and livestock) and for crude oil.

Figure 5. World output price indices by scenario, spread across commodities for baseline (2030, 2010=100)



Source: Authors' elaboration.

In the baseline price indices of all three commodity groups have increased with an increasing amount moving from primary food (101) to processed food (106) and non–food (111) commodities. This reflects the projected increase in income per capita (see Figure 11). With rising incomes, consumption shifts away from primary products to more processed food and non–food expenditures (which includes services). A growing population with higher incomes puts more pressure on non–food prices promoting a structural shift of the economy away from agriculture.

In the baseline scenario the world population increase of 20 percent results in only a limited increase in primary agricultural commodities by 2030 (1.4 percent). Primary production can increase through intensification (increasing the amount of labour, capital and fertilizer or feed per unit of land or livestock) and by extensification (increasing the amount of agricultural land governed by the land supply function discussed above). The alternative population assumptions vary rather symmetrically for most regions, amounting to about 6 percent points lower or higher population growth. The response of the primary sector is not symmetrical, the increase in primary food prices is higher (plus 8 percent points) than the decrease (minus 4 percent points) with a smaller global population by 2030. This asymmetric response points to the impact of the land supply function, making it increasingly costly to expand the agricultural area.

Figure 5 presents aggregated results which masks some of the variety across commodities inside each aggregate, as indicated for the baseline scenario by the error bars. Whereas in the baseline the primary food aggregate shows a modest increase of 1.4 percent, several prices drop among which wheat (minus 3.3 percent) and pig and poultry prices (minus 5.4 percent). On the opposite side we find oilseeds with a significant price increase (8.4 percent), followed at some distance by sugar cane and beet prices (5.2 percent).

Closer examination of the results reveals that India accounts for a large proportion of the world share of wheat output and prices in India fall by 10 percent over 2010–2030. This is the result of wheat productivity in India projected to grow at double the rate of the world average. A significant proportion of the fall in Indian prices translates into reduced world wheat prices.

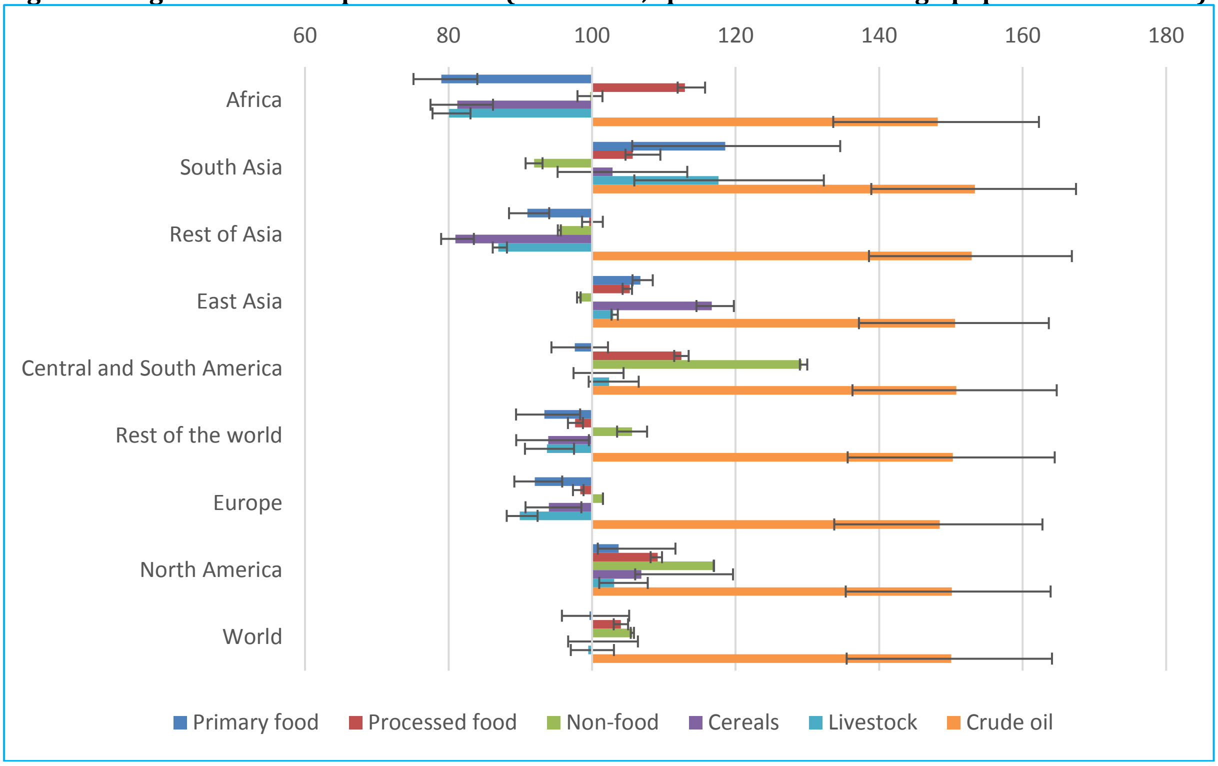
The declining prices for pig and poultry are surprising given the projected increases in per capita income and a tendency to switch to meat with rising incomes. Prices can decline due to projected yield shocks increasing the efficiency in feed (both in production of feed from crops and in direct use of crops for livestock production). Pig and poultry production does not require land, removing the competition with other primary sectors for this limited resource, resulting in declining prices with double digit numbers in almost regions. Exceptions to this pattern are prices increase in China and Brazil. With over 40 percent of production occurring in China the net world impact remains limited to a modest price decline. The feed productivity shocks are even at the high end in the case of China. The opposite price development is therefore not due to differences in supply side shocks but to a different consumption pattern – China's demand for pig and poultry is substantial. The projection of more than tripling income per capita causes demand to outstrip the increased efficiency of production and pig and poultry prices rise in China. This mutes the price declines in the rest of the world, resulting in a modest net price decline at the global level.

The primary commodities with a price increase, oilseeds and sugar cane and beet, are linked to biofuels whose demand is regulated through mandates. In all scenarios we impose blending levels rates for petrol based on current policies. The impact of these mandates gets reinforced by the global economic growth, increasing the demand for (blended) petrol and thus for biofuels. The demand for petrol rises even with a high exogenously projected increase in crude oil prices in the baseline (50.3 percent), the highest of all non–food commodities. In the two population scenarios the oil price is endogenous and reacts strongly to changes in demand due to varying population assumptions (15 percent point decrease or increase relative to the baseline).

ii. Price developments by region

MAGNET models international bilateral trade using an Armington approach, i.e. regional markets are segmented. As a result regional variations in drivers result in regional price differences not fully eliminated through international trade adjustments. Figure 6 takes a closer look at regional differences in price developments. The bars for the baseline indicate the spread of these regional prices for the low and high population scenario. Generally the low population scenario corresponds with the low price marker and vice versa for the high population scenario. This pattern is reversed however for non–food commodities in South and East Asia.

Figure 6. Regional baseline price indices (2010=100, spread for low and high population scenario)



Source: Authors' elaboration.

Whereas the average world price hovers around the 2010 level prices for all commodity groups but crude oil (exogenously set in the baseline scenario), there are obvious regional differences. Prices for primary food drop considerably in Africa (79), the poorest region, largely driven by price drops in cereal (81) and livestock (80). Prices of processed food rise (113) where non–food prices remain at their 2010 level. Rest of Asia also shows a drop in primary food (91), cereal (81) and meat (87) prices, but here prices of processed food remain stable while non–food prices drop (95).

South and East Asia show a pattern with rising primary food prices and less correlation with either cereals or meat prices. In the case of South Asia cereals price response is a lot more muted (103). This is due to rapid wheat yield increases projected for India, as discussed previously. In East Asia cereal prices do increase considerably (117) but in this case the meat price response is moderated (103). Livestock feed efficiencies are projected to increase fast but these productivity gains are outstripped by increased demand resulting from fast rising incomes in China.

The spread in prices in the low and high population growth scenario is highest for South Asia. This is not due to larger differences in population projections for this region (see Figure 2), there are regions with a similar divergence in population projections and a less strong response. Delving deeper in the results shows that it is the interplay between limited available land and a high share of domestic production in consumption which makes the agricultural price react strongly to the alternative population scenarios in South Asia.

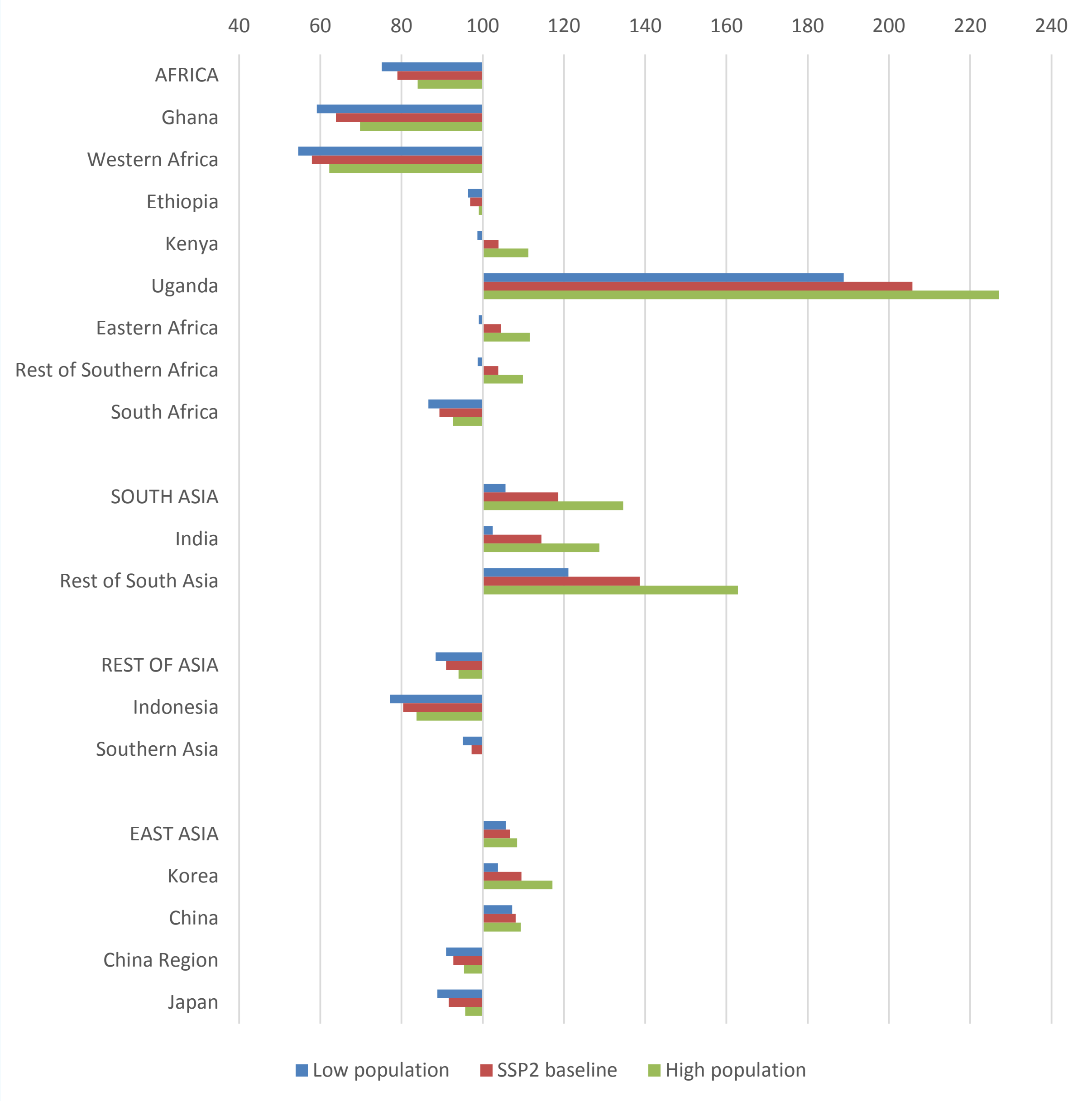
The regional aggregates in Figure 6 may mask some diverging patterns at the country level. To assess whether this is the case we take a closer look at the countries in the poorest regions (Africa and Asia) zooming in on primary food which is key for the poor. Figure 7 shows regional changes in primary food prices for each of the scenarios. The results for the three aggregated Asian regions are dominated by the developments in the largest constituent countries (India, China and Indonesia). The African aggregate includes more regions and shows opposite developments within the continent.

Uganda immediately stands out with a doubling of the 2010 price for primary agricultural products in the baseline (206) and an additional 21 point increase when including the high population projections. These large price increases are the result of the interplay between a very high projected population growth (78 percent in the baseline and 87 percent in the high population projections) and a very low land supply elasticity (0.05). The population growth provides a strong demand push increasing the demand for land. The low supply elasticity indicates that limited land can be brought into production to meet the additional demand, resulting in a strong land price response.

The contrasting case is Ghana where prices drop substantially in the 2010–2030 period. Population growth in Ghana is substantial as well (47 percent in the baseline), but in this case land can be brought into production more easily with a land supply elasticity of 0.4. This dampens the price response through the land channel but this provides only part of the story.

In all scenarios population growth is translated to the various labour types at the same rate, increasing the supply of labour. In the case of Ghana the unskilled labour type is further subdivided in six different types of unskilled labour (see ANNEX A), among which is a dedicated type of unskilled labour used only in agriculture. By definition non–agricultural sectors do not use agricultural labour, implying perfect market segmentation for this type of labour. With no endogenous mechanisms in the current model to transform labour types and not including a rural–urban migration in the translation of population growth to labour types in the scenario definition, the high population growth generates a high lock–in effect. The fast growing agricultural labour force cannot move to other sectors causing agricultural unskilled wages to drop by 80 percent, which translates into lower prices of agricultural commodities.

Figure 7. Regional and country primary food price indices by scenario (2010=100)



Source: Authors' elaboration.

Closer examination of the cost structures reveals that the self–employed unskilled labour type distinguished in Uganda is also only used in primary agriculture, once again introducing a perfect market segmentation with the non–agricultural sectors. With the high population growth the self–employed wage also drops dramatically. The limited effect on the agricultural prices in Figure 7 is due to the specification of the production function for agricultural sectors (see ANNEX B) limiting the possibilities to substitute labour or capital for land (substitution elasticity of 0.1 in the relevant nest) despite the huge price increase for land. There is a strong increase in fertilizer use in Uganda (which can directly substitute for land, with a maximum substitution elasticity of 0.75), but clearly not enough to offset the effects of the land price increase.

Indonesia is the third country having an unskilled labour type referred to as agricultural (see ANNEX A), but the cost structures reveal use of this labour type in both primary agricultural and the food processing sectors. MAGNET includes an agricultural–

non–agricultural factor market segmentation, allowing labour to move between agricultural and non–agricultural employment albeit not perfectly. Combined with a more modest population growth the ability to move out of primary agriculture results in a more moderate reduction in agricultural prices in Indonesia.

These varying developments underscore the critical role of factor supply elasticities when projecting long term developments in agriculture, identified by Hertel *et al*. (2016) as a main source of the widely diverging projections for crop prices and land use found in the literature.

In the context of high prices supporting poverty reductions for the rural poor reported in the empirical literature (Headey, 2014; Ivanic and Martin, 2014), the lower agricultural prices in Africa (the second poorest region in our model) does not bode well for poverty reductions. We will take a closer look at the factor price developments, which determine household income, later in this chapter. First we examine the changes in global agricultural production.

b. Production changes and contribution by region

There are regional variations in the size and sometimes even direction of the shocks. Combined with different comparative advantages changes in the regional allocation of production are to be expected, which we explore in this section.

i. Global distribution of production

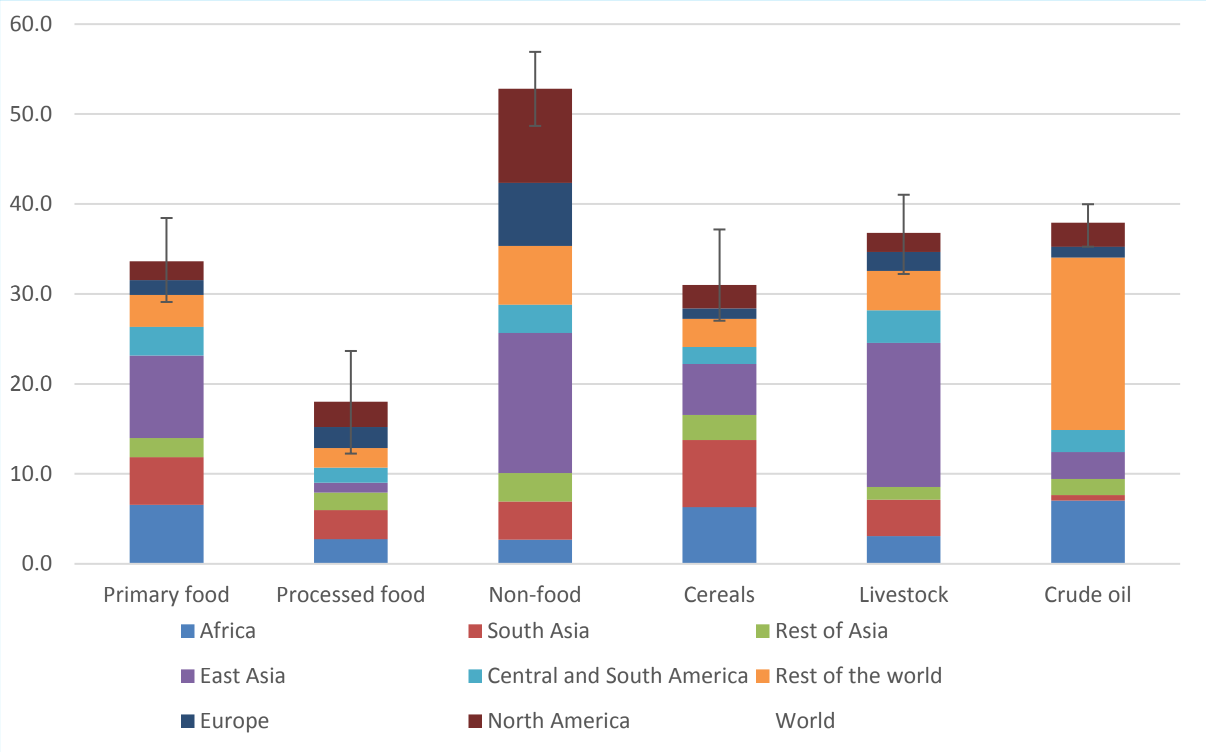
Figure 8 presents the percentage change in the global production and the contribution of each region to this change. The bars indicate the spread in projected production for the low and high population scenario. The projected increase in both population and income, as shown in the GDP per capita developments in Figure 11, creates a strong demand–side push on production. Inelastic demand for food implies that with higher incomes demand for non–food items increases more, raising its shares in global private consumption from 87 to 91 percent. The rise in income is also reflected by the strong increases in demand for livestock (37 percent), especially pig and poultry which increases by 48 percent. As discussed above, the increased demand for pig and poultry meat in China plays an important part in the latter, with East Asia accounting for 65 percent of the global increase in the sector's production.

Differences in comparative advantage and consumption patterns is obvious in the increased cereal production being concentrated in Asia (rice and wheat). Across the commodities Asia accounts for a large part of the increases in production, which is not surprising given that by 2030 one in every two persons is projected to be Asian.

Another clear case of comparative advantage is the dominance of the rest of the world region in the increase in oil production. This region includes key producers in the Middle East, Central Asia and Russia, capturing 51 percent of additional oil production. They are followed at a respectable distance by Africa contributing another 21 percent.

At the aggregated level in Figure 8 the high and low price scenario give a balanced spread in total projection of output changes. The 6 percent point difference in population size by 2030 translates in roughly 4.5 percent point higher or lower primary food production, 5.7 percent point difference in processed food and 4.1 percent point change in non–food production.

Figure 8. Increase in world production and contribution by region (% change 2010–2030 and spread for high and low population scenario)

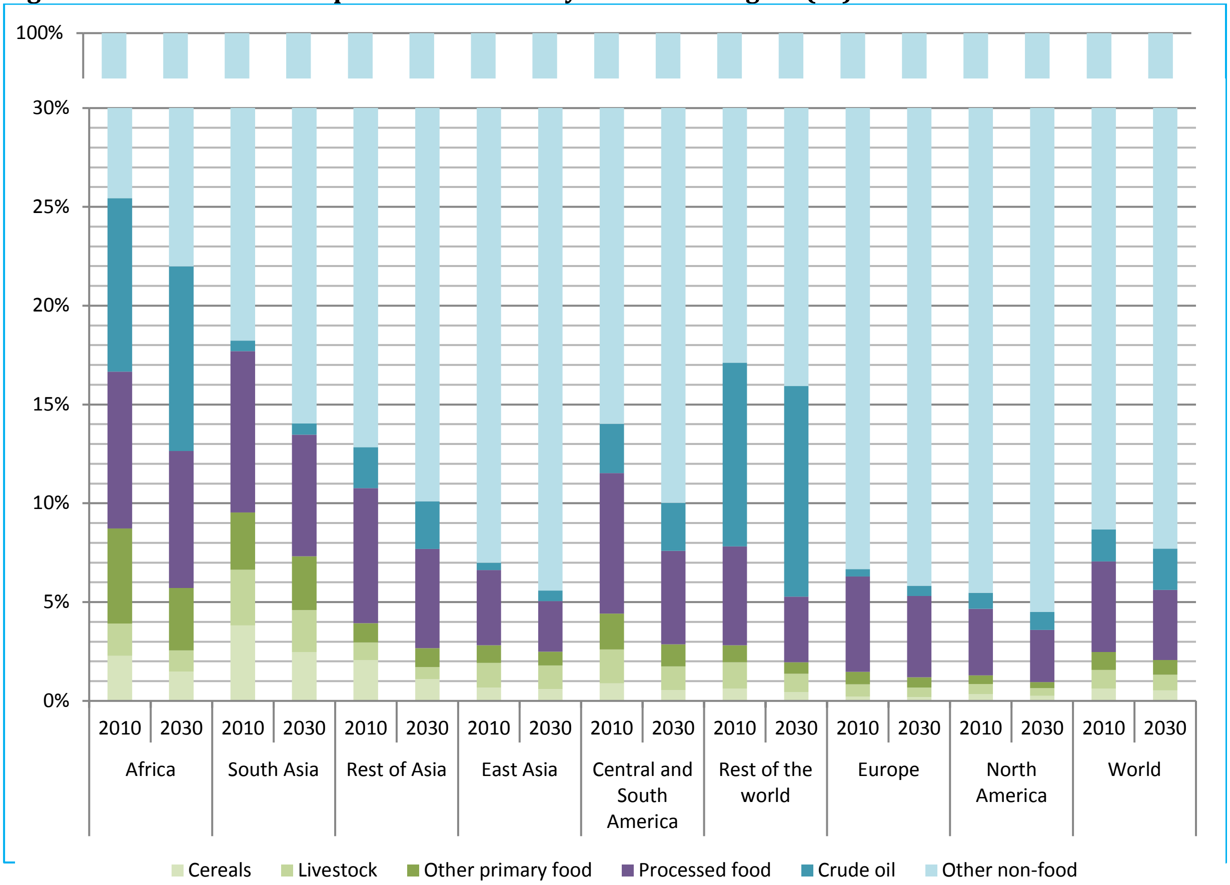


Source: Authors' elaboration.

ii. Size of sectors in the economy

Different growth rates by commodity group and varying contributions from regions to the global changes in production suggest that the sectoral composition of regions might change. Figure 9 explores this by presenting the shares of commodity groupings in total production value for the baseline scenario. The economic importance of the primary sector drops at world level (from 2.5 to 2.1 percent of production value). The largest drops are in the poorer regions (Africa and South Asia) and in South and Central America. The share of non–food production rises in all regions, and especially so in regions where primary production contributes less to the total value of production. Apart from Central and South America the relative importance of oil production increases in all regions, most notably in the Rest of the World aggregate (from 9.3 to 10.7 percent).

Figure 9. Baseline share in production value by sector and region (%)



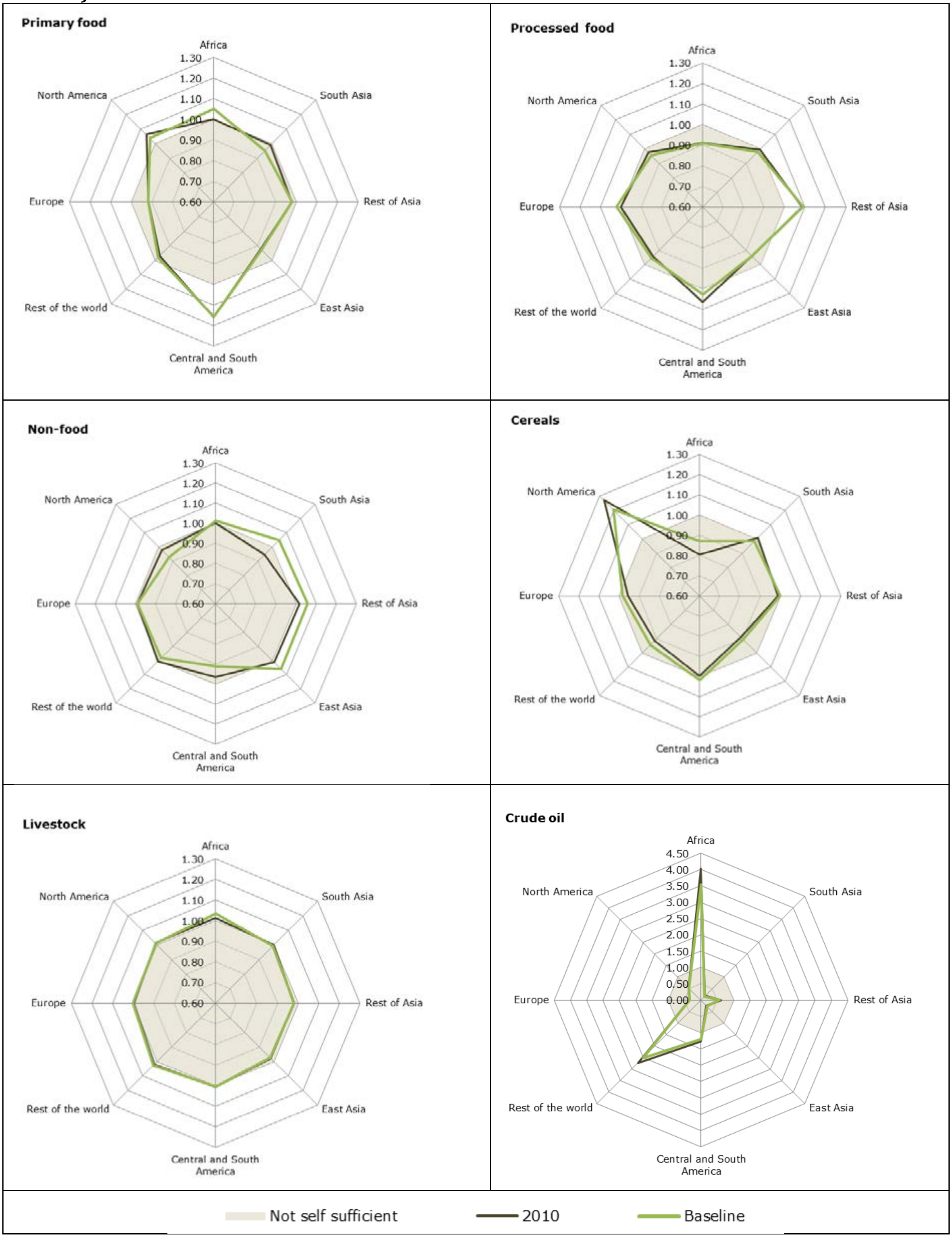
Source: Authors' elaboration.

iii. Regional self–sufficiency in food

Above we highlighted the importance of population growth on demand and the large share of the world population living in Asia. Whereas 52 percent of the people will be living in Asia by 2030, only 20 percent of the cultivated land will be located there. This suggests a possible high reliance on imports. To explore this question Figure 10 presents the self–sufficiency ratios (production over demand) for the world regions in 2030. The coloured area represents the ratios of less than one, i.e. where demand cannot be covered by domestic production. Lines outside this area indicate production surpassing demand.

For the primary food aggregate the three Asian regions indeed need to import, as does Europe and the Rest of the World. Eventually this food has to come from the Americas and Africa where production is expected to exceed demand by 2030. Note that these ratios do not say anything about bilateral trade; surplus can either be directly exported to Asia or it can sustain their consumption indirectly by exports to net importing regions which then export to Asia. The African region is projected to move from self–sufficiency in 2010 to being a net exporter by 2030 for primary agricultural products, whereas North America remains net exporting but to a lesser extent (1.06 in 2010 versus 1.04 in 2030). There are no reversals in position, the largest change occurs in South Asia moving from being close to self–sufficiency in 2010 (0.99) to almost the largest importer (0.93, with Europe remaining the largest importer at a constant 0.92).

Figure 10. Self–sufficiency ratios by world region for key commodities in 2030 (production/ demand)



Source: Authors' elaboration.

Figure 10 also presents the self–sufficiency ratio for processed foods, demand for which will increase as income per capita rises. Here the regional pattern is different from primary agriculture, with Rest of Asia, Europe and South and Central America being net suppliers to the rest of the world. Rising incomes spur demand for processed food in

Central and South America and their self–sufficiency ratio drops from 1.07 in 2010 to 1.03 by 2030. European incomes are already high and food demand is therefore less sensitive to further income growth. They move from self–sufficiency in 2010 (1.0) to being a net supplier in 2030 (1.02).

Neither at the aggregate level nor at the more detailed commodity level the alternative population scenarios offer a noticeable difference from the baseline evolution. For readability these are therefore excluded from Figure 10. The commodity graphs, however, highlight specific regional patterns for different primary commodities.

When comparing cereals and livestock products, we see a much more balanced pattern for livestock. Livestock self–sufficiency ratios are remarkably constant between 2010 and 2030. Even in East Asia, including China, the self–sufficiency ratio remains almost constant moving from 0.98 to 0.97 in 2030. Pig and poultry is an important part of livestock production in China. A distinguishing feature of this primary sector is that no land is used in production. This increases the scope for intensification and substitution of inputs when demand rises. The stable self–sufficiency ratios of around 1 indicate that the different regional contributions to changes in global livestock production in Figure 8 are mostly responses to differences in regional demand developments due to differences in projected increases in GDP per capita.

c. Patterns in economic growth

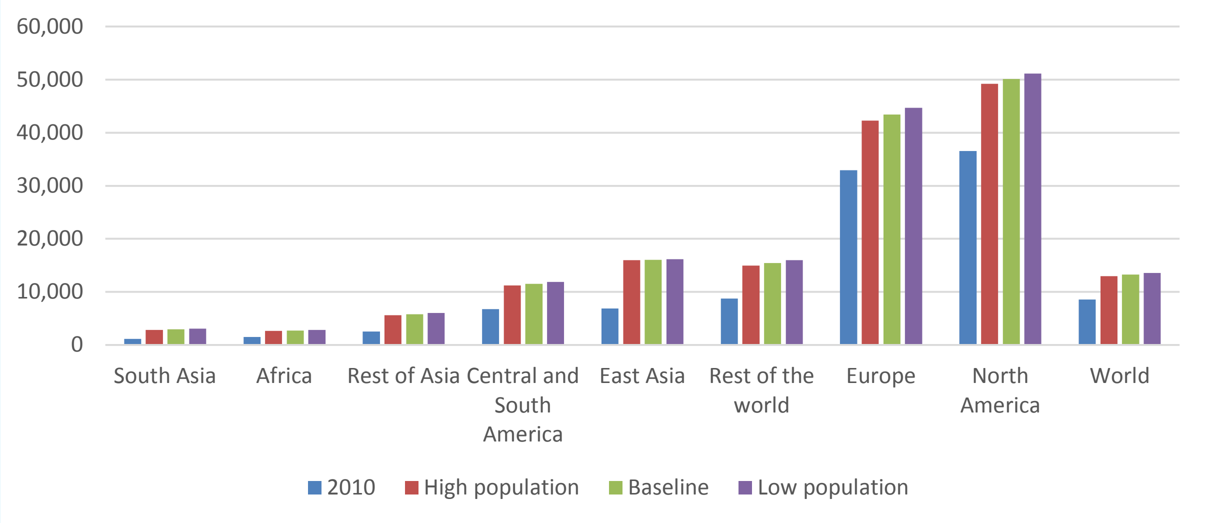
Regions are affected differently by the key drivers in each of the scenarios. This is in part due to country–specific differences in the shocks, for example the population increase by 79 percent in Uganda while declining by 9.8 percent in Ukraine (see Figure 2).

i. GDP per capita developments

Figure 11 shows GDP per capita developments by world regions ranked on 2010 GDP per capita income. The baseline developments in both GDP and population growth are exogenously determined. In the SSP2 baseline strong increases in GDP per capita are projected for the low income regions. East Asia, and especially China, will grow particularly fast overtaking the Rest of the World (consisting of mainly Central Asian countries). Incomes in the three poorest regions are projected to double, but should remain well below the 2010 income levels of the other regions.

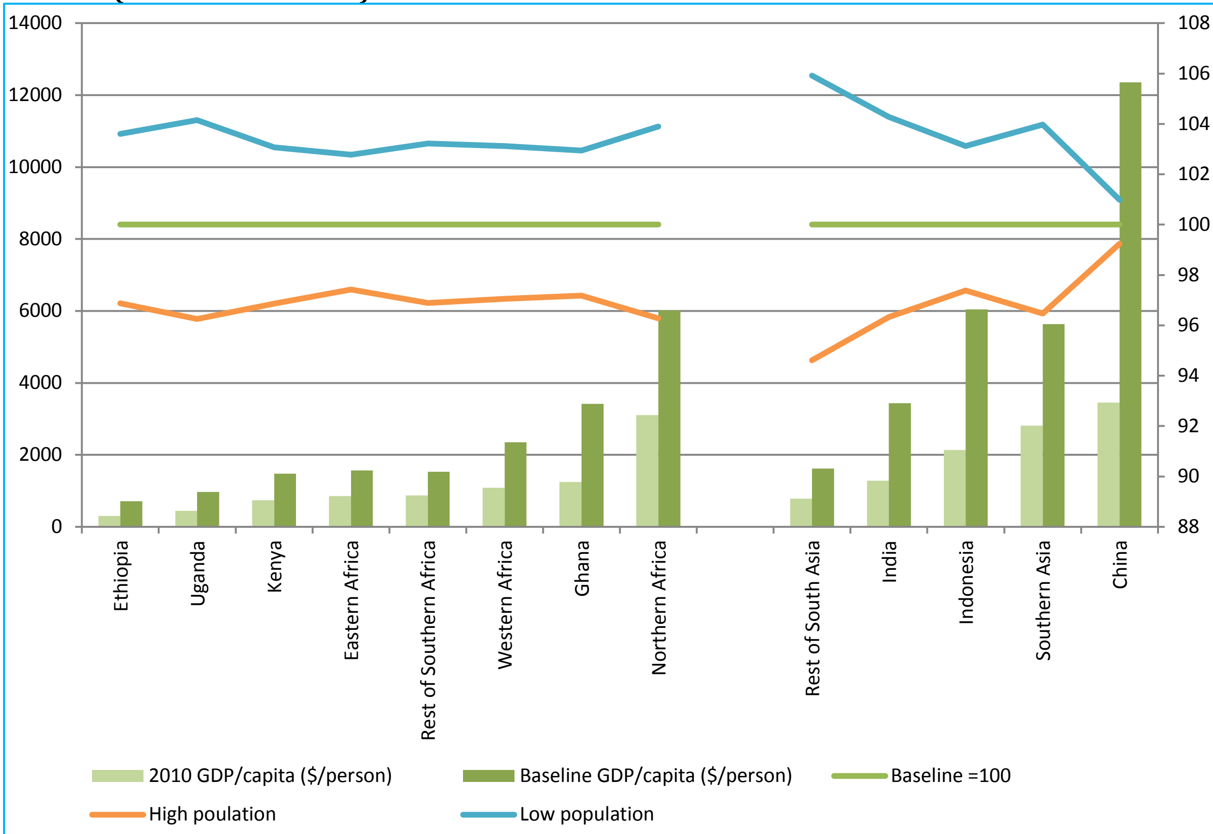
The high and low population scenario result in a small but rather symmetrical divergence from the baseline with lower population increasing GDP per capita in all regions. GDP in all regions declines in the low price scenario relative to the baseline, by 5.1 percent for the world as a whole. An increasing GDP per capita in the low population scenario thus implies that the smaller increase in workforce (causing the lower GDP) is outdone by a lower number of mouths to feed in all regions (thus raising the GDP per capita).

Figure 11. GDP per capita by world regions and scenario (US$/person)



Source: Authors' elaboration.

Figure 12. GDP per capita growth in selected countries (US$/person) and deviation from the baseline (baseline 2030=100)



Source: Authors' elaboration.

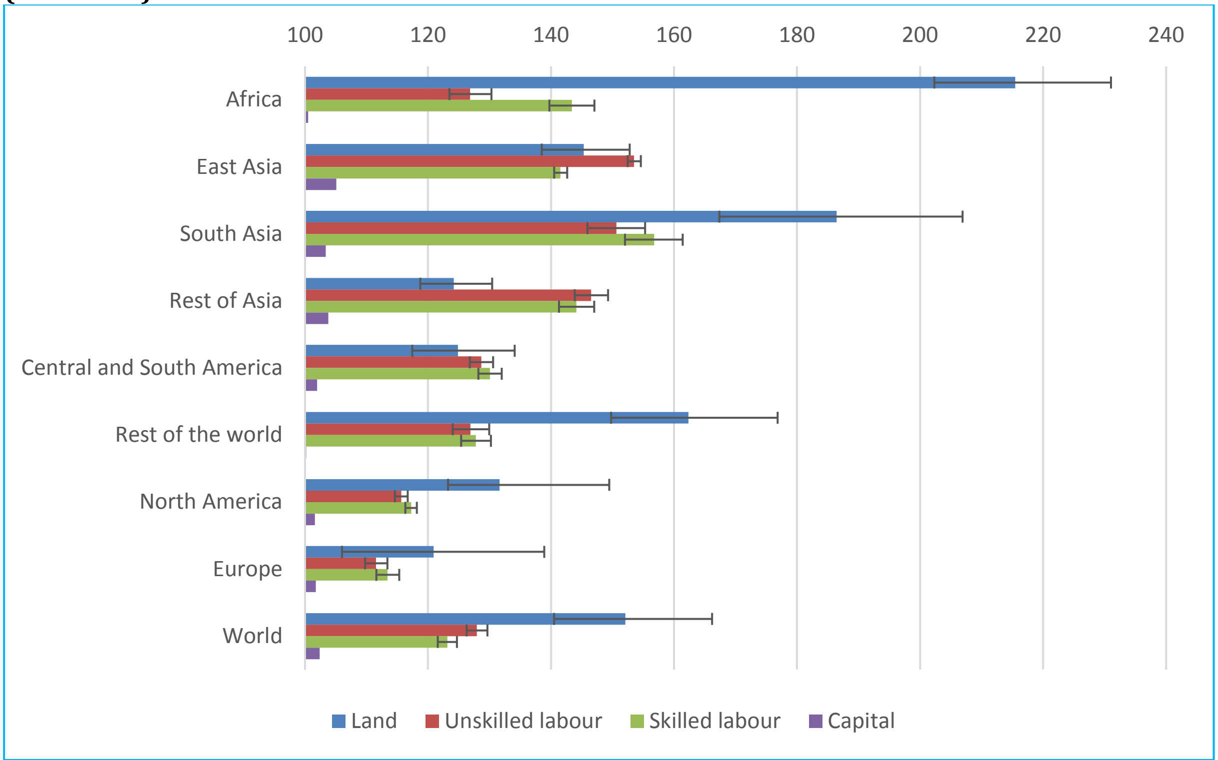
To get a better understanding of possible diverging developments in the poorest regions we zoom in on the regional developments within Africa and Asia, focussing on the poorest regions in Figure 12. The growth in GDP per capita in China immediately comes to the fore. GDP is projected to grow more than 2.5 times while population growth with 2.9 percent is among the lowest. Population assumptions varying between 1.4 and 4.5 percent are insignificant relative to the GDP growth reducing the deviation from the baseline developments to a 1 percent point margin for China.

The wide margin between the high and low price scenario for the Rest of South Asia region (including Pakistan and Sri Lanka) is due to a combination of relatively high baseline population growth (32.8 percent) with a high variation (about 26 percent higher or lower) causing the projected population size to vary considerably. There are regions with similar variations, like in Southern Asia (including Thailand, Cambodia and Laos). In the rest of South Asia, however, a modest GDP growth makes the impact of diverging population projections more visible.

ii. Factor price developments

GDP per capita developments provide an indicator of the available income per person, ignoring issues of income distribution. The allocation of this income is governed by factor or endowment ownership. Factor incomes change due to a combination of growth in endowments and changing prices. For example, population growth translates to an exogenous growth of labour (we assume no changes in employment rates), while land supply is endogenous driven by the demand for land. Figure 13 explores changes in factor prices in the 2010–2030 period.

Figure 13. Baseline real land and labour prices in 2030, spread for low and high population scenario (2010=100)



Source: Authors' elaboration.

The increased land prices in Africa really stand out. Delving deeper into the results it is revealed that land prices increase strongly in all African countries, but especially in Uganda through a combination of high population growth and limited land supply as discussed earlier. The push for land is also reflected in a strong expansion of agricultural area of 20 percent in Africa, only surpassed by a 23 percent increase in the Rest of Asia.

Globally the increase in land is limited to 4 percent and in some regions it even declines (North America, Europe and the Rest of the World).

Skilled and unskilled labour both grow at the population rate, changes in wage rate however vary by type. In Africa, South Asia and the Americas skilled labour wages rises more. Given identical growth rates this implies a shift of labour income from unskilled to skilled. With richer households typically owning more skilled labour this suggests a worsening of the labour income distribution. The opposite pattern, with unskilled labour income rising more, is observed for the Rest of Asia, East Asia and the world as a whole. Thus globally, changes in return to labour are expected to improve poverty indicators in East and Rest of South Asia. The opposite trend is actually observed in the poorest regions, Africa and South Asia.

Compared to land and labour, capital prices hardly change in any of the scenarios due to its link with GDP growth. With limited price changes, capital growth almost fully determines capital income. Regions with high GDP growth thus have a strong increase in capital income. With the poorer regions expected to grow faster (see Figure 10) this will reduce global poverty. But with richer households typically owning more capital the within country income distribution is likely to worsen.

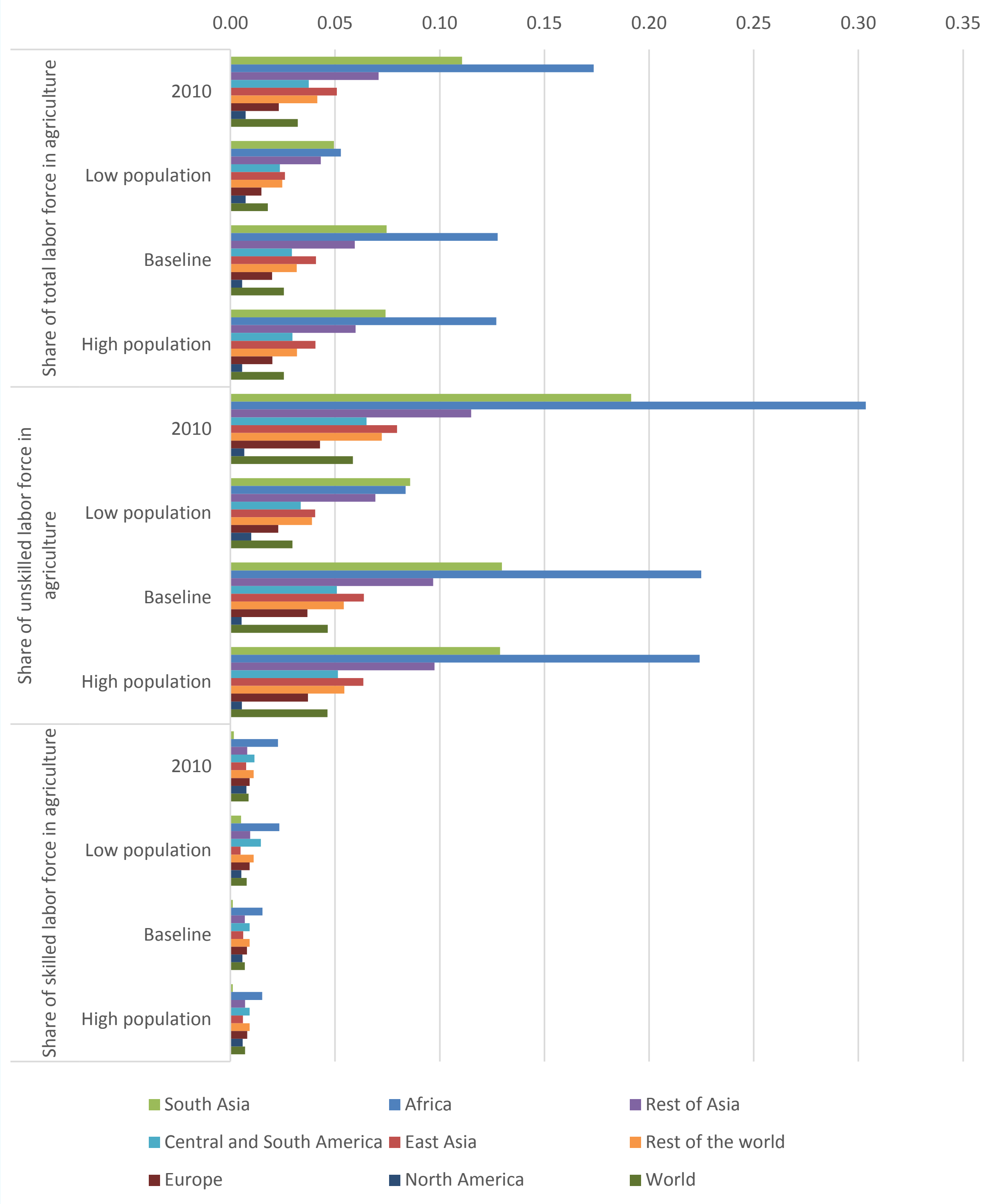
The developments in Figure 13 present national level developments. The implications for poverty depend on the distribution of factor ownership over households, at which we take closer look in the next chapter.

iii. Agricultural and non–agricultural labour

MAGNET includes a segmented labour market which captures the empirically observed wage differentials between agricultural and non–agricultural sectors. This segmented labour market slows but does not prevent movement of labour out of agriculture. The only exception is for a few household regions with more detailed factor endowments. In the case of Ghana and Uganda there is one type of labour endowment only used in agricultural sectors. Not being demanded by other sectors the market for this type of labour is effectively fully segmented, which has a downward pressure on the wages when population grows (the earlier discussed lock–in effect).

Figure 14 presents the share of the labour force employed in agriculture for 2010 and in 2030 by scenario. The top part shows the share of the total labour force employed in agriculture. The regions are ranked from poor to rich based on the 2010 GDP per capita (see Figure 11). Overall the typical decline in agricultural employment with rising incomes is clearly visible. The only exceptions are the relatively low shares of agricultural labour in Central and South America given its per capita GDP and most notably the high share of labour in Africa. Comparing the cost structure of Central and South America to the other regions shows a relatively high use of capital in agriculture, more comparable to the North American region than other regions at a similar income level. Comparing Africa and South Asia (which includes India and Bangladesh) the latter has more low skilled labour opportunities in manufacturing and services.

Figure 14. Share of total labour force in agriculture and by skill type for 2010 and 2030 by scenario



Source: Authors' elaboration.

Comparing across scenarios the rather symmetrical changes in population do not have a symmetrical effect on the share of labour employed in agriculture. There is a sharp drop with lower population growth, most notable in Africa which in the low population scenario no longer stands out. Changes in the other regions are more modest but in all, the share of people in agriculture drops when populations grow slower. In other words, slowing of population growth speeds the process of labour leaving agriculture. The increase in available people with high population growth does not retain a higher share of people in agriculture. Differences with the baseline are barely noticeable. If anything the pattern is less consistent with the share dropping the least in Africa, East and South Asia while rising slightly in all other regions.

The two bottom panels in Figure 14 show the share of labour employed in agriculture by skill type. Not surprising the shares of skilled labour active in agriculture are really low in all regions. Compared to unskilled labour there is much weaker link between GDP per capita and share of skilled agricultural labour.

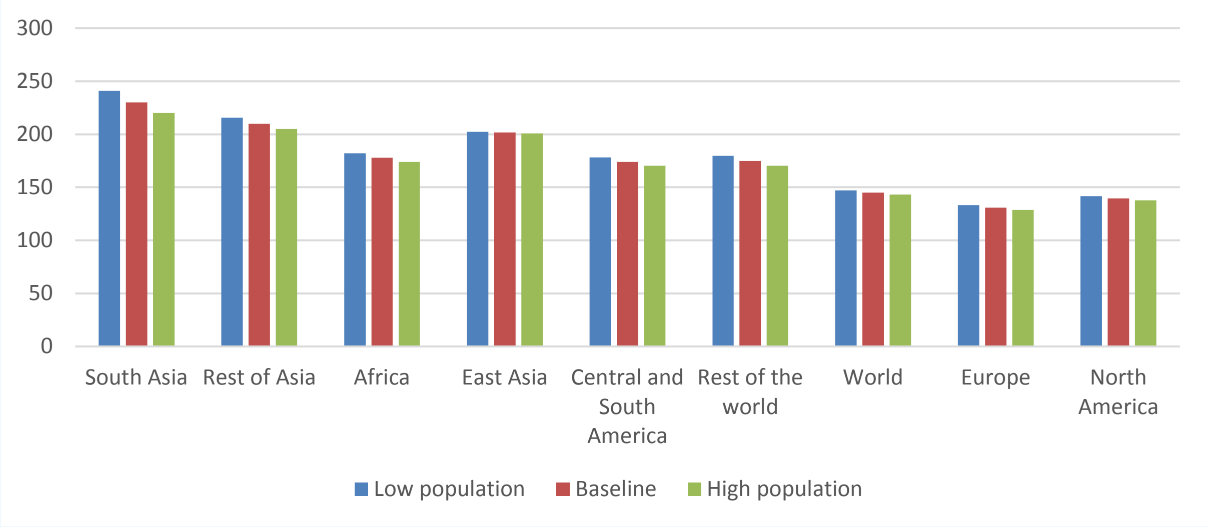
V. Household impacts

So far we have focused on national level results although changes in income distribution were implied when discussing factor price developments. In this chapter we take a closer look at the household level developments in income and consumption.

a. Household income

To get a better idea of the household level impacts, Figure 15 presents changes in private expenditures which amounts to changes in household income, excluding savings. The regions are ranked from left to right in increasing expenditures per capita in 2010. The ordering is different from the GDP per capita ranking for the lower income regions (see Figure 11). Total national income, as represented by GDP is allocated to private household expenditures, government expenditures and savings; different allocation shares can change the ranking when using private expenditures.

Figure 15: Private real expenditure per capita by scenario and region in 2030 (2010=100)



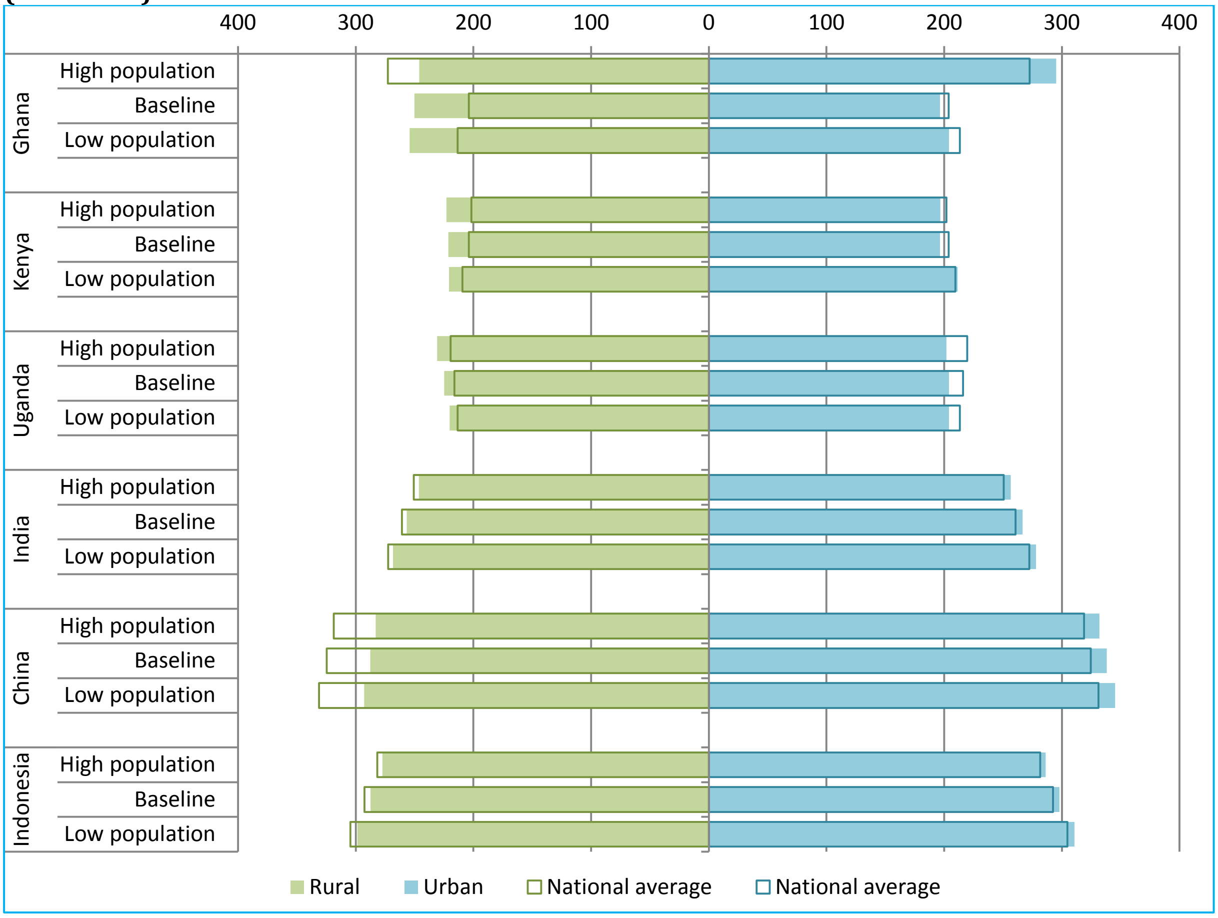
Source: Authors' elaboration.

With a low population growth total national expenditures or incomes are smaller, and vice versa for the high population scenario. The change in total income, however, is smaller than the change in population. Thus, as with GDP, the smaller amount of expenditures needs to be distributed over an even smaller number of people, thus resulting in a higher income per capita in Figure 15 for the low population scenario. The opposite occurs in the high population scenario, resulting in a declining income per capita when there are more mouths to feed.

The per capita income changes depicted in Figure 15 implicitly assume a perfectly equal distribution of income. The actual available income per capita depends on the income distribution. Currently MAGNET includes several representative household types for six countries: Ghana, Kenya, Uganda, India, China and Indonesia (see ANNEX A for a description of the household types by region). These household types have different factor endowments and therefore different income developments given the varying developments of factor prices (Figure 13). These varying endowments are the only source of diverging incomes in the current model set–up, rural–urban migration or differential access to education changing the labour skills are not accounted for.

To ease the comparison we aggregate the household types for the six household countries into rural and urban households when comparing the household expenditures or income per capita (Figure 16). For quick reference we added the national average change in per capita income as an outline to both the rural and urban pane.

Figure 16. Rural and urban real expenditure for household countries by scenario in 2030 (2010=100)



Source: Authors' elaboration.

Comparing the divergence from the national average across countries' rural households in the three African countries gain more than the national average, with the exception of the rural household group in Ghana in the high population scenario. In the Asian countries, on the other hand, the rural households gain less than the urban households, and especially so in China. By definition the opposite pattern holds for the urban households. These different developments are due to variations in factor endowments of the households. In Africa land prices rise considerably (see Figure 13), which benefits the rural households. In Ghana the urban households do not own any land, in Kenya they own a very small amount while in Uganda one rural household owns about all the available land (a small fraction is owned by urban farm households). The income of the expanding land area and increasing land prices in Africa thus accrues to the rural households and in the case of Uganda to only one of the two rural household types.

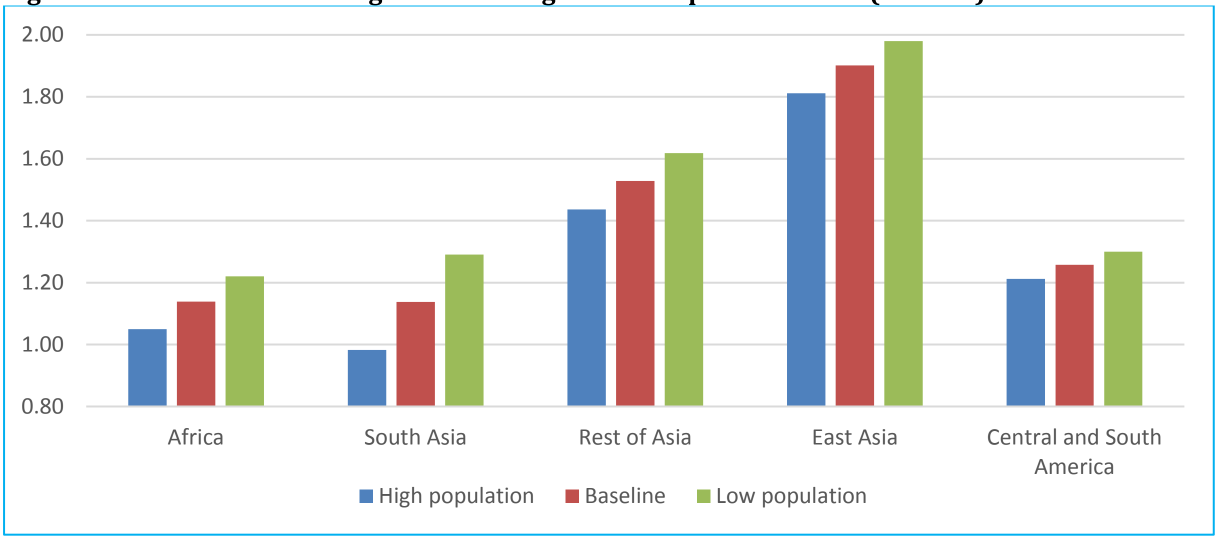
In South Asia, which includes India, land prices rise considerably as well. The effect for India is not visible in Figure 16 since the source data used to distinguish household types lacked data on land ownership. Lacking better information land ownership is distributed across all household types based on total factor income from non–land endowments, and this channel of variation in household income effects is lost. In the case of Indonesia the source data indicate land ownership of all household types, probably through rental markets. Again this mutes the land channel for diverging household impacts.

China is the only of Asian household regions in MAGNET where all land ownership sits with the rural household. In contrast to the African cases here the rural household gains less than the national average. China is part of the East Asia region where land prices rise more modestly and are surpassed by rises in unskilled labour wage (see Figure 13). However, digging into the results factor prices were detected in China to develop differently from the regional aggregate. Prices of skilled labour rise most, followed by unskilled and then land. With the urban household holding all skilled labour they gain more than the rural household.

b. Changes in accessibility of staples

The previous section focused on changes in income per capita for different household types. This analysis is only possible for a small subset of regions with additional household details. To get a broader indication of the poverty impacts of the baseline and alternative scenarios we compute changes in the accessibility of staples in the poorer regions of the world.

Figure 17. Ratio of unskilled agricultural wage to cereal prices in 2030 (2010=1)



Source: Authors' elaboration.

The ratio of the unskilled agricultural wage to cereal prices, shown in Figure 17, is a measure of the purchasing power of poorer rural households in each region. An increase in the ratio means that wages are rising faster than cereal prices and indicates that the economic status of poorer households is improving. All the regions experience wages that rise faster than cereal prices in the baseline scenario. A lower population growth, making labour more scarce thus increasing wages, further improves the purchasing power of poorer rural households in all the regions with the largest gains in South Asia. Conversely, higher population growth erodes the purchasing power of poorer households by lowering unskilled wage; to such an extent in South Asia that the purchasing power of the rural poor drops below 2010 levels.

c. Changes in household consumption patterns

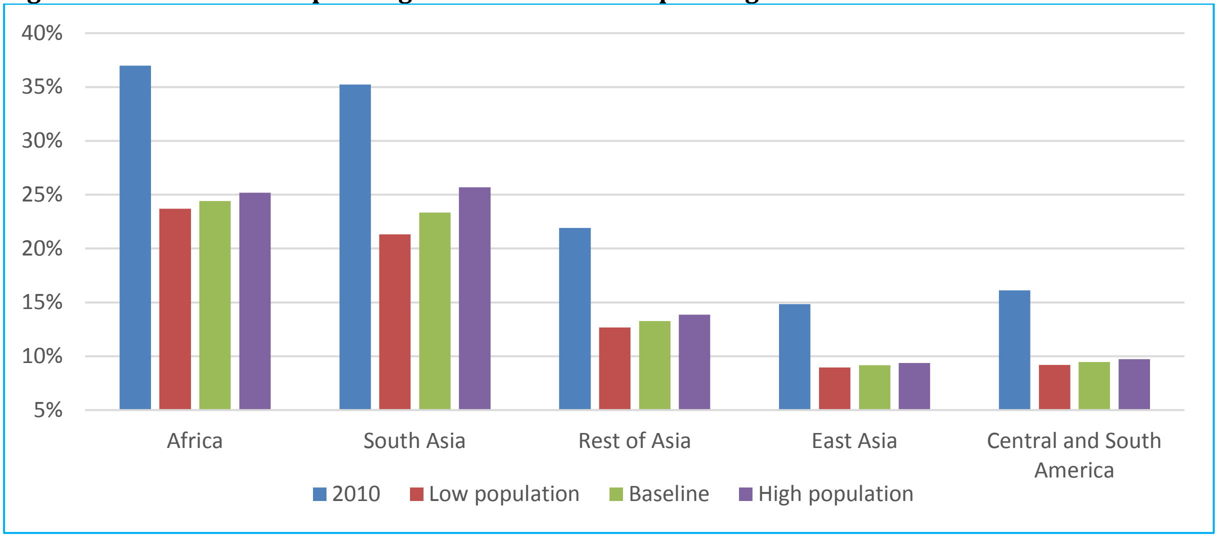
The baseline projections show a marked increase in income per capita for all regions. The household analysis shows that all household types gain considerably: the one gaining the least across countries with more household detail is the richest urban household in Kenya experiencing a 92 percent increase in income per capita. The poorest household type in each country gains at least 130 percent. This rise in income can be expected to change the consumption pattern, both in terms of the share of food in total expenditure as in the type of food consumed.

As expected the rising incomes lead to a marked reduction in the share of household expenditure spent on food, Figure 18. As an indicator of food security, this reduction suggests an improvement in the food security of the average household in each region, with the greatest improvements seen in Africa and South Asia. Lower population growth leads to a further reduction in the share of income spent on food. In part by reducing the cost of purchasing food and in part because the lower rate of population growth in this scenario raises per capita incomes further (see Figure 15).

High population growth offsets some of the gains of economic growth while the additional population growth in this scenario lowers the per capita income. The result is a slight increase in the share of income spent on food in all regions. By this measure, food security improves in the low population and slightly worsens in the high population scenario. The greatest impacts are in Africa and South Asia where population projections associated with the high and low price scenarios change the most.

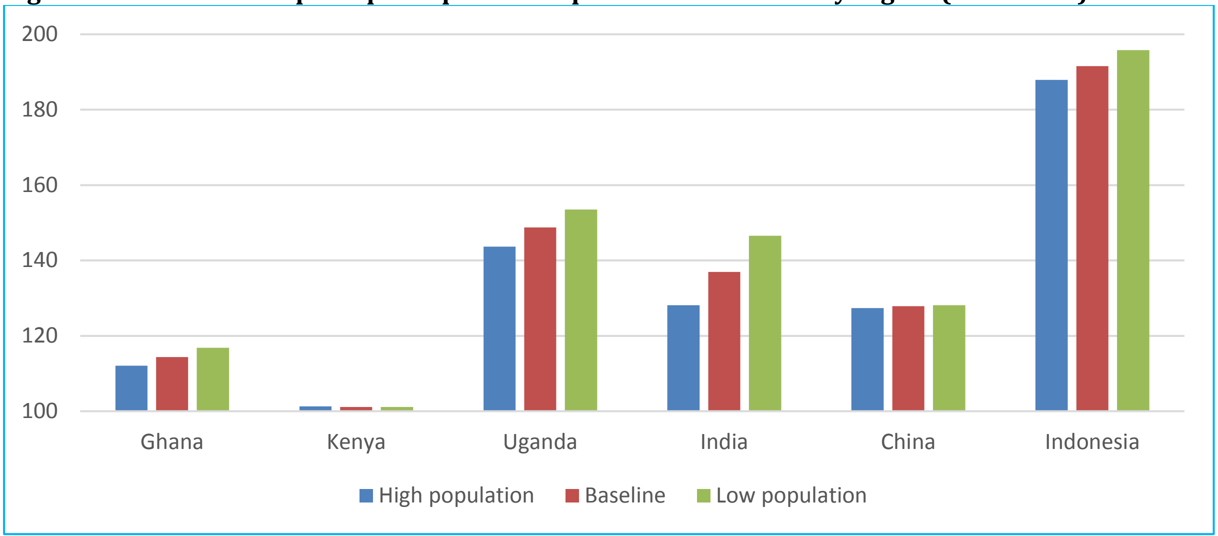
Since national averages as in Figure 18 may obscure variations across households we also assess the changes in per capita food consumption for the poorest household types in the regions with additional household details (Figure 19). According to the household types in MAGNET, the poorest households are rural households in the Coastal area in Ghana, rural farms households in Uganda, rural first decile households in Kenya and India, rural households in China and rural agricultural employee households in Indonesia.

Figure 18. Share of food spending in total household spending



Source: Authors' elaboration.

Figure 19. Food consumption per capita of the poorest households by region (2010=100)



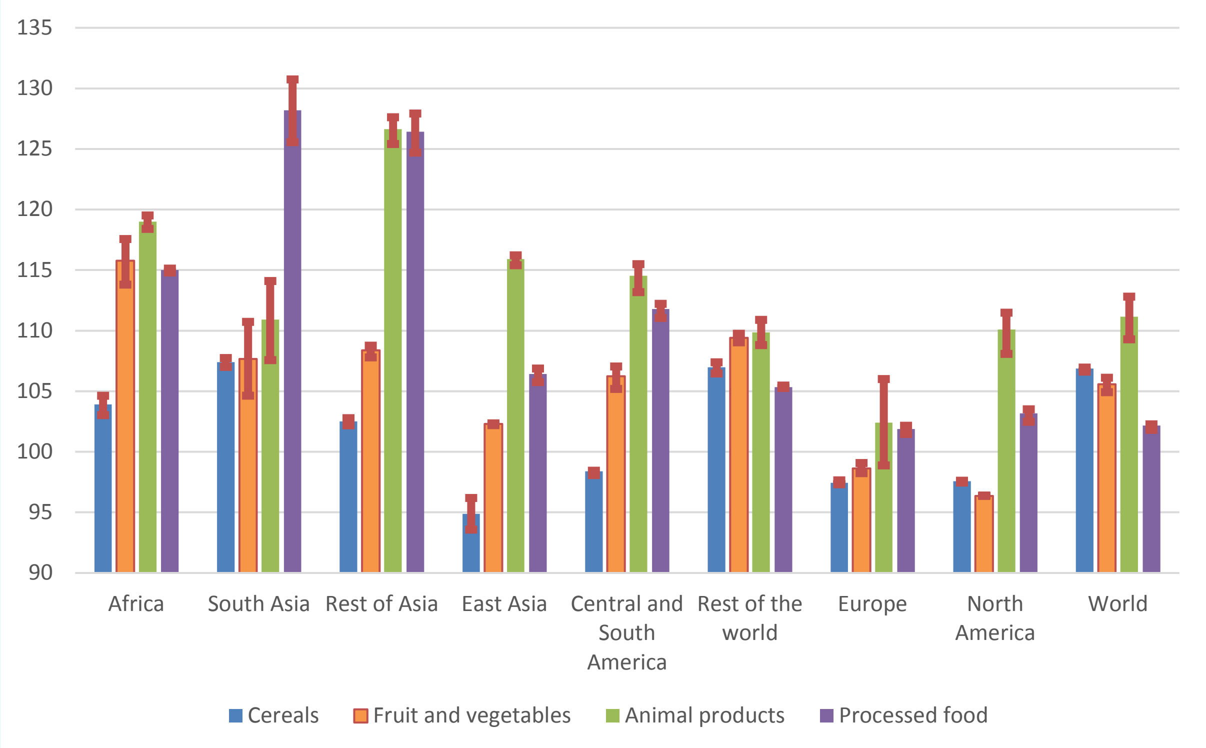
Source: Authors' elaboration.

Baseline growth improves the consumption of the poorest households in all countries with the exception of Kenya where the poorest household maintains the 2010 food consumption per capita in all scenarios. The greatest increase occurs in Indonesia, almost doubling its food consumption by 2030. Lower population growth leads to an improvement in food consumption for the poorest household in all countries, with large increases of 5 and 10 points above the baseline growth in Uganda and India. High population growth has the opposite effect reducing per capita food consumption between 9 points in India and Uganda and 0.5 points in China.

With rising incomes the types of food purchased by household changes, the so called Engel curve. From a nutritional point of view not only the quantity of food but also the type of commodities consumed is important. Figure 20 explores the changes in food consumption per capita by major category: cereals, fruit and vegetables (important for their nutritional content), animal products and processed food. The spread in the two alternative scenarios is included as well, with the high population scenario reducing the per capita consumption relative to the baseline (due to the larger number of mouths to feed).

In Africa, South Asia and Rest of Asia baseline economic growth results in a small increase in cereal consumption, while in East Asia and Central and South America cereal consumption drops below the 2010 levels. The latter two regions already have higher GDP per capita incomes in 2010 than what is expected to be attained by 2030 in Africa, South Asia and Rest of Asia. Their rising incomes are not spent on satisfying immediate calorie needs through cereals but on increased demand for animal protein and processed food, as illustrated by the earlier discussed strong increase in pig and poultry consumption in China. A similar pattern is observed for the highest income regions, Europe and North America. South Asia stands out by the large percentage increase in processed food consumption relative to the 2010 levels. It is the poorest region in the model and the projected income increases that raises the share of processed foods in these four categories from a low level (0.55) to a slightly higher level (0.60), where the richer regions account for 74 percent and more. South Asia in this way starts catching up in terms of processed food dominating household consumption.

Figure 20. Food consumption per capita by major food category and world region (2010=100, spread in high and low population scenario)



Source: authors' elaboration.

VI. Concluding remarks

This study focuses on exploring alternative (agricultural) price developments through scenario analysis using the MAGNET CGE model where prices are not given but result from supply and demand interactions. The drivers causing higher or lower agricultural prices therefore take centre stage in the analysis and allow us to explore the implications of uncertainties surrounding projections.

The SSP2 baseline projections at the core of this analysis has an optimistic view of economic growth, projecting an economic convergence with most poorer regions catching up in terms of GDP per capita. Given the initial large disparity in income levels, however, global inequality persists. Despite massive economic growth, prices of primary agricultural products only rise slightly in the 2010–2030 period, and for some commodities like cereals and other animal products (pig and poultry) even a decline is expected due to projected increases in efficiency. Global agricultural land increases by 4 percent, with strong regional variations and opposite movements. In Africa high population pressure increases land areas by 20 percent while the cultivated area slightly declines in Europe and North America. We do not find large changes in food self–sufficiency of the regions.

Exploiting the household level detail in some regions included in MAGNET shows the potential of higher prices to increase incomes. Rural households deriving the majority of their income from land experience an increase in per capita income.

Globally unskilled labour gains proportionally in relation to skilled labour, suggesting a reduction in poverty. However, in the poorest regions (Africa and South Asia) the opposite pattern is observed. The gains of unskilled labour in the populous regions of East and Rest of Asia drive the global pattern, suggesting that still a large number of poor people will catch up to some extent.

a. Population

The variations in population growth projections (plus or minus 28 percent at the global level) are so large as to undo the positive economic effect of an increase in labour supply; relative to the baseline incomes per capita decline in the high price scenario (and increase in the low price scenario). The changes in population projections especially affect primary agricultural prices for which demand is inelastic. In the case of the high population scenario this implies that all the extra mouths need to be fed even if prices rise. Furthermore, with incomes per capita declining, a larger share of expenditures is directed towards food (Engel's Law). The population growth when coupled with effectively fully segmented agricultural and non–agricultural labour markets in Ghana and Uganda decimates agricultural wages. We will return to the lessons learned from these really specific cases later.

b. Location of land available for expanding agriculture matters

The second critical driver of alternative price developments, both across scenarios as for regional differences in price developments within a scenario, is the availability of land for agricultural expansion. In MAGNET land supply is endogenous and agricultural land can expand at an increasing cost. The ease with which land can expand affects the increase in land prices and thus output prices. Easier access to additional land (and a lock–in of labour) in Ghana was found to result in the lowering of agricultural prices compared to 2010, while the opposite in land–scarce Uganda occurred despite a similar lock–in of agricultural labour.

c. Yield improvements can surpass demand increases

Projection of yield improvements, or in other words technical change, is a critical factor for the projected prices. In the baseline a drop in global wheat prices was traced to fast yield gains in a single major producer, India. On the other hand increases in feed efficiency significantly lowered the price of pig and poultry despite a rising demand for animal products accompanying the rise in incomes. Only in China and Brazil demand rises so much as to result in an increase in prices, the effect in China being so big as to almost undo the price decrease at the global level. These critical yield improvements are exogenous to the current model and do not require investments in R&D nor a delay in availability of technological advances and may hence overestimate the positive impacts of technical change.

d. Rural–urban migration matter for positive income effects of higher prices

The literature stands divided over whether higher food prices are good or bad for poverty. Empirical evidence (Headey, 2014) supports the view that higher prices reduce poverty in the longer term due to the positive income effect on poor households engaged in agriculture.

Using a CGE model we do not exogenously set prices in our study but instead construct alternative scenarios which increase or decrease prices relatively to the baseline by varying the projected population growth. With higher population growth driving the high prices their impact becomes negative – although GDP and income rise when more labour becomes available, the extra number of people to feed reduces the income per capita at the national level. The cause of the increase in agricultural prices thus plays a critical role in the income effect.

For a limited number of countries we could assess different income developments for rural and urban households. Although in the three African countries rural households gained more than urban households, these gains were not always greater in the high population scenario which corresponds to higher prices. In the three Asian countries with household detail the income per capita was lower for rural households and declines further with higher population (and prices). Critical in these regional differences is the ownership of land by Asian urban households, either by construction due to lack of data, as for India, or following from the source data, as for Indonesia. With the higher prices in our scenarios following from an increase in population which lowers the wages, the positive impact on rural incomes comes only through land. Then only if land is concentrated with the rural households they experience a positive impact of higher prices in line with the findings of Heady.

Hertel (2016) looking at the food security impacts of climate change identified the need to improve our understanding of the rate at which countries urbanize since positive effects of higher food prices only accrue to the poor earning an income from agriculture. Hertel, *et al*. (2016) when surveying and reconciling widely diverging estimates of agricultural developments concluded that while improved estimation of agricultural supply elasticities is of outstanding importance for understanding future agricultural developments, it has been a neglected area in research for decades. The findings in this study, and especially those for Ghana, show that these two areas of research are intertwined.

A recent and unique feature of MAGNET is the inclusion of both multiple household types and additional factor detail in a global model. This extension aimed at both tracing the impact of sectoral developments on household incomes and food security, and capturing the impact of different consumption patterns by household type on aggregated demand and prices. When specifying the scenario shocks no explicit attention was paid to patterns of urbanization, i.e. the labour endowments of all household types were assumed to grow at the population rate. Due to the additional detail in unskilled labour types in Ghana this simplifying assumption led to a strong lock–in effect by exaggerating the growth in agricultural labour and underestimating the growth in unskilled urban labour. The effect is so large as to reverse the sector price developments compared to other regions with similar drivers. Albeit not realistic, this specification highlights how capturing urbanization trends is not only important for measuring price and income effects of food price changes, as stressed in Hertel (2016), or for capturing differences in rural and urban diets for food demand. The urbanization trends directly affect the factor supply, labour but possibly also capital, thus playing a crucial role for projecting future changes in agricultural production and prices as stressed by Hertel, *et al*. (2016). The Ghana results also show that the potential for rural–urban migration not only affects the number of poor which may benefit from the positive income effect of higher food prices. The rate at which a growing rural population is able to migrate determines whether or not the positive income effect for the rural population will materialize.

e. Pointers for policy responses to higher prices

This study focused on exploring the impact of alterative assumptions on key drivers of agricultural prices. Although we did not assess different policy options some policy related observations can be made. In order to engage the wage and land channel generating the positive income effect for households earning their income in agriculture, any (short–term) mitigation of negative purchasing power effects of increasing food prices should not affect the transmission of higher prices to farmers.

Additionally the income effect may not occur if labour gets locked in the rural areas, as we found in Ghana due to the specific set–up of the current model and scenario. This could be an argument for enabling rural–urban migration to raise the incomes of the remaining rural households when population grows. In the urban areas, however, there is no positive income effect from higher food prices (only a negative price effect). Given the reality of limited government control over rural–urban migration the policy measures will need to mitigate the impact of higher food prices on net–buyers of food. In the longer run income–earning possibilities need to be created in the urban areas to not only cushion impacts of higher food prices on the current urban poor, but also allow a growing rural population to relocate to urban employment. If urban income–earning possibilities do not develop, people may get locked into poverty in the rural areas and no gains are reaped from higher agricultural prices, neither by the urban nor by the rural households.

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ANNEX A

Model aggregation

The MAGNET database has to be aggregated to arrive at a model database with feasible dimensions. Here we describe the results in terms of regions, sectors and commodities and for the regions with household detail the household typology and additional factor details.

Table A.1.Mapping of model regions to reported regions

Region	*Countries*
Africa	Northern Africa Ghana Western Africa Ethiopia Kenya Uganda Eastern Africa Rest of Southern Africa South Africa
South Asia	India Rest of South Asia
Rest of Asia	Southern Asia Indonesia
East Asia	Korea China China Region Japan
Central and South America	Central America Brazil Rest of South America
North America	Canada North America Mexico
Europe	Western Europe Central Europe Rest of Western Europe Rest of Central Europe
Rest of the world	Turkey Ukraine Region Central Asia Russia Region Middle East Oceania

Source: Authors' elaboration.

Model regions

The 140 GTAP countries and regional clusters available in Version 9 are further aggregated into 33 regions.

Table A.2. MAGNET model regions

No.	*Code*	*Description*
1	CAN	Canada
2	USA	North America
3	MEX	Mexico
4	CAM	Central America
5	BRA	Brazil
6	RSM	Rest of South America
7	NAF	Northern Africa
8	GHA	Ghana
9	WAF	Western Africa
10	ETH	Ethiopia
11	KEN	Kenya
12	UGA	Uganda
13	EAF	Eastern Africa
14	RSF	Rest of Southern Africa
15	ZAF	South Africa
16	EU16	Western Europe
17	EU12	Central Europe
18	RWE	Rest of Western Europe
19	RCE	Rest of Central Europe
20	TUR	Turkey
21	UKR	Ukraine Region
22	CAS	Central Asia
23	RUR	Russia Region
24	ME	Middle East
25	IND	India
26	RSA	Rest of South Asia
27	KOR	Korea
28	CHN	China
29	CHR	China Region
30	SEA	Southern Asia
31	IDN	Indonesia
32	JPN	Japan
33	OCE	Oceania

Source: Authors' elaboration.

Model sectors and commodities

The GTAP database distinguishes 57 sectors which each produce a single commodity (Narayanan, *et al.* 2015). The MAGNET database splits several of these sectors to add more details needed for the model extensions (animal feed, fertilizers, biogasoline and biodiesel). MAGNET also allows sectors to produce more than one commodity. Splitting and aggregating sectors depending on the level of detail needed results in a model database with 36 sectors and 38 commodities.

Table A.3. MAGNET model regions

Category	*Nr*	*Code*	*Description of sector*	*Code*	*Byproduct*
Primary sectors	1	pdr	Paddy rice		
	2	wht	Wheat		
	3	gro	Cereal grains nec		
	4	hort	Vegetables, fruit, nuts		
	5	osd	Oil seeds		
	6	c_b	Sugar cane, sugar beet		
	7	crops	Other crops		
	8	oagr	Other agriculture		
	9	ctl	Cattle, sheep, goats, horses		
	10	oap	Animal products nec		
	11	rmk	Raw milk		
	12	fsh	Fishing		
	13	frs	Forestry		
Processed food	14	cmt	Meat: cattle, sheep, goats, horse		
	15	omt	Meat products nec		
	16	vol	Vegetable oils and fats		
	17	mil	Dairy products		
	18	pcr	Processed rice		
	19	sugar	Sugar and molasses		
	20	cvol	Crude vegetable oil	oilcake	Oil cake
	21	pfd	Processed food		
Animal feed	22	feed	Animal feed		
Fertilizers	23	fert_n	fertilizer nutrient n		
	24	fert_p	fertilizer nutrient p		
	25	fert_k	fertilizer nutrient k		
Energy	26	coa	Coal		
	27	c_oil	Crude oil		
	28	gas	Gas		
	29	gdt	Gas manufacture, distribution		
	30	petro	Petroleum and coal products		
	31	ely	Electricity		
	32	biog	Biogasoline	ddgs	Dried distillers grain
	33	biod	Biodiesel		
Industry	34	lowind	Other low tech industry		
	35	highind	Other high tech industry		
Services	36	svcs	Services		

Source: Authors' elaboration.

Additional factor detail in household regions

GTAP standard distinguishes 5 types of endowments: land, unskilled labour, skilled labour, capital and natural resources[5]. Where the national SAMs used for the household region provide more details on endowments, we split the GTAP factors. The result is various level of factor detail for regions with more than one household type.

Table A.4. Additional land detail in Ghana

Code	*Description*
Land1	Land in coastal zone
Land2	Land in forest zone
Land3	Land in southern savannah zone
Land4	Land in northern savannah zone

Source: Authors' elaboration.

Table A.5. Additional unskilled labour detail in Ghana, Kenya, Uganda, India and Indonesia

Code	*Ghana*	*Kenya*	*Uganda*	*India*	*Indonesia*
UnSkLab1	Self–employed labour (agriculture), Coastal Zone	Unskilled labour	Self–employed labour	Rural unskilled	Agricultural labour
UnSkLab2	Self–employed labour (agriculture), Forest Zone	Semi–skilled labour	Unskilled labour	Urban unskilled	Production transport equipment operation & manual
UnSkLab3	Self–employed labour (agriculture), Southern Savanah Zone				
UnSkLab4	Self–employed labour (agriculture), Northern Savanah Zone				
UnSkLab5	Elementary labour (agriculture and non–agriculture)				
UnSkLab6	Non–agricultural unskilled labour				

Source: Authors' elaboration.

Table A.6. Additional skilled labour detail in India and Indonesia

Code	*India*	*Indonesia*
SkLab1	Rural skilled	Clerical sales & services labour
SkLab2	Urban skilled	Professional managerial (including military)

Source: Authors' elaboration.

[5] In the last GTAP database release additional detail in labour endowments is added, increasing the number of labour endowments to 5. This additional detail has not yet been incorporated in the MAGNET database.

Additional household detail in household regions

The household module distinguishes multiple households allowing a better assessment of the distributional consequences of economic developments. Data from national SAMs are used to split the single private household in the GTAP database in two or more types of households. Again, due to variations in source data the level of detail varies by region.

Most of the national SAMs are taken from the IFPRI data repository:

Ghana: Breisinger, Clemens; James Thurlow; Duncan, Magnus. 2007. A 2005 Social Accounting Matrix (SAM) for Ghana. Ghana; Washington, D.C.: Ghana Statistical Services (GSS); International Food Policy Research Institute (IFPRI)(datasets). http://www.ifpri.org/dataset/ghana

Kenya: Kiringai, Jane; Thurlow, James; Wanjala, Bernadette. 2006. A 2003 Social Accounting Matrix for Kenya. Nairobi; Washington, D.C.: Kenya Institute for Public Policy Research and Analysis (KIPPRA); International Food Policy Research Institute (IFPRI)(datasets). http://www.ifpri.org/dataset/kenya-social-accounting-matrix-sam-2003

Uganda: Thurlow, James, 2012-08-09, "Replication data for: A 2007 Social Accounting Matrix for Uganda", http://hdl.handle.net/1902.1/18662 International Food Policy Research Institute [Distributor] V2 [Version]

India: Ganesh-Kumar, A. and M. Panda, 2009. A 2006-2007 Social Accounting Matrix for India. Unpublished mimeo. Indira Gandhi Institute of Development Research, Mumbai.

China: Zhang, Yumei; and Diao, Xinshen. 2013. A 2007 Social Accounting Matrix for China: Methodology and Results. Washington, DC: International Food Policy Research Institute (IFPRI) (datasets). http://hdl.handle.net/1902.1/21132

Indonesia: Indonesia: Social Accounting Matrix, 1995. 2003. Washington, D.C.: International Food Policy Research Institute (IFPRI)(datasets). http://www.ifpri.org/dataset/indonesia

Table A.7: Additional household detail in in Ghana, Kenya, Uganda, China, India and Indonesia

Code	*Ghana*	*Kenya*	*Uganda*	*India*	*China*	*Indonesia*
hh1	Accra	Rural D1	Rural farm	Rural <10	Rural	Agricultural employees
hh2	Urban coast	Rural D2	Rural non–farm	Rural 10–30	Urban	Small–medium farmer households (own < 1ha)
hh3	Urban forest	Rural D3	Kampala metro	Rural 30–70		Large farm households (own >1 ha)
hh4	Urban south	Rural D4	Urban farm	Rural 70–90		Rural low–income non–agricultural households
hh5	Urban north	Rural D5	Urban non–farm	Rural > 90		Rural high–income non–agricultural households
hh6	Rural coast	Rural D6		Urban <10		Urban low–income non–agricultural households
hh7	Rural forest	Rural D7		Urban 10–30		Urban high–income non–agricultural households
hh8	Rural south	Rural D8		Urban 30–70		
hh9	Rural north	Rural D9		Urban 70–90		
hh10		Rural D10		Urban > 90		
hh11		Urban D1				
hh12		Urban D2				
hh13		Urban D3				
hh14		Urban D4				
hh15		Urban D5				
hh16		Urban D6				
hh17		Urban D7				
hh18		Urban D8				
hh19		Urban D9				
hh20		Urban D10				

Source: Authors' elaboration.

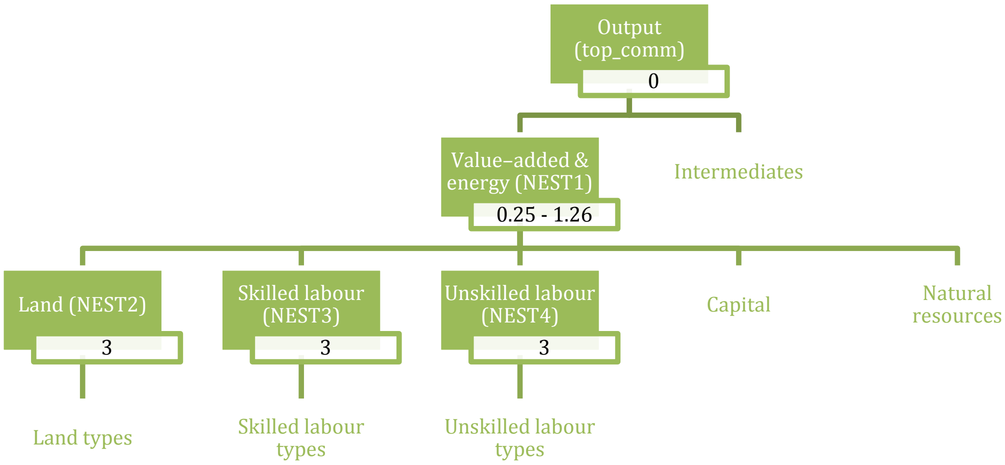
ANNEX B

Production structures and elasticities

The production tree module in MAGNET allows the user to define nested CET production functions for dedicated groups of sectors. These structures are defined using parameters. To ease the interpretation we here list the implied structures and elasticities used in the current study.

GTAPMF – GTAP production structure with multiple factors

Applies to: fsh, frs, cmt,omt,vol,mil,pcr,sugar,cvol,pfd,fert_n,fert_p,fert_k,gdt,ely, coa, c_oil, gas, biod, lowind, highind, svcs, cgds.
Characteristic: standard GTAP production structure with multiple factor types.

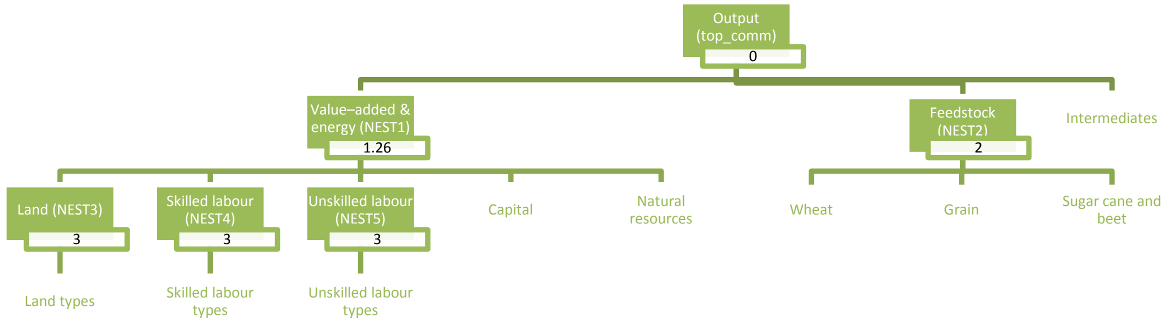


Source of elasticities:

- Top_comm: GTAP – ESUBT
- NEST1: GTAP – ESUBVA (varies for agricultural, industry and services sectors, not region specific)
- NEST2: 3 – assumed to be easy to substitute among land types
- NEST3: 3 – assumed to be easy to substitute among labour types
- NEST4: 3 – assumed to be easy to substitute among labour types

BIOG – Biogasoline production

Applies to: biog.
Characteristic: standard GTAP structure with additional nest for substitution among types of feedstock used in producing biogasoline.

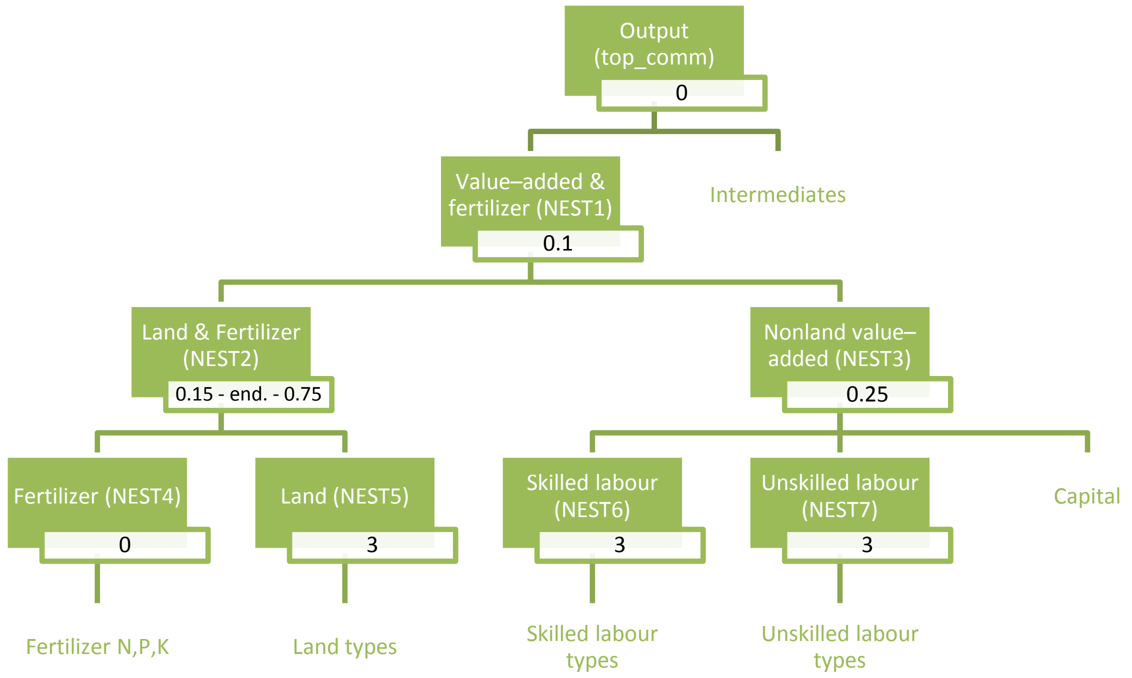


Source of elasticities:

- Top_comm: GTAP – ESUBT
- NEST1: GTAP – ESUBVA (not region specific)
- NEST2: 2 – assumed to be relatively easy to substitute among feedstock
- NEST3: 3 – assumed to be easy to substitute among land types
- NEST4: 3 – assumed to be easy to substitute among labour types
- NEST5: 3 – assumed to be easy to substitute among labour types

CROPS – Crop production

Applies to: pdr, wht, gro, hort, osd, c_b, crops, oagr.
Characteristic: limited substitutability of land with other factors and possibility to substitute fertilizer for land.

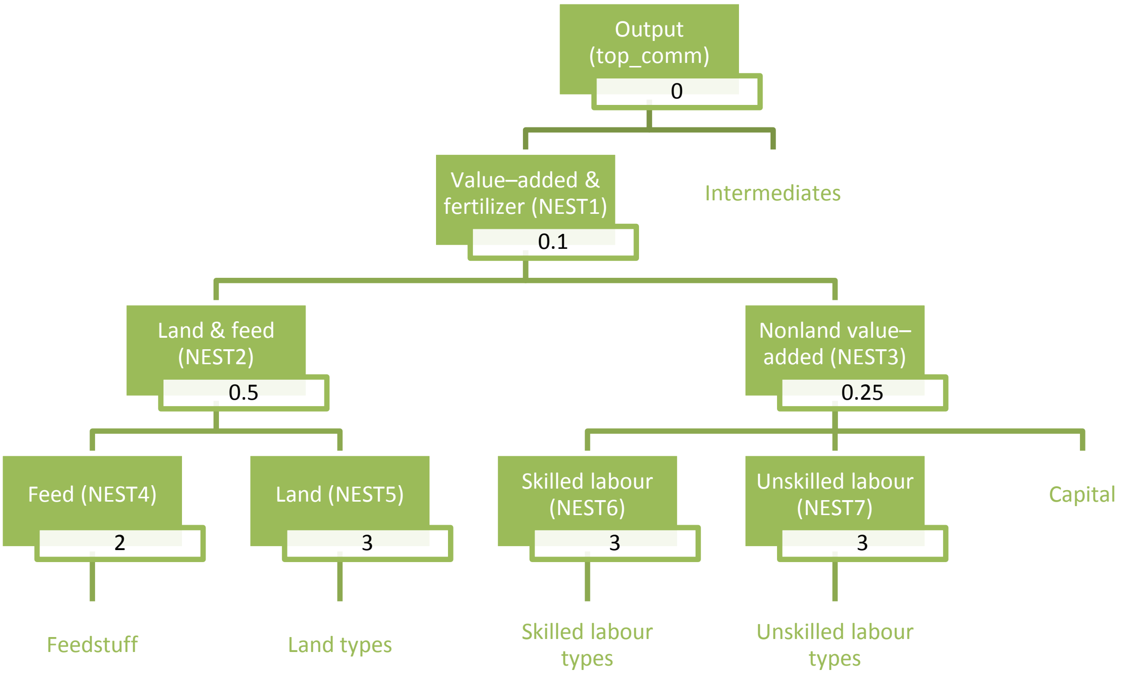


Source of elasticities:

- Top_comm: GTAP ESUBT
- NEST1: set low to limit substitution possibilities for land
- NEST2: endogenous linked to income per capita in between 0.15 and 0.75
- NEST3: GTAP ESUBVA (not region specific, pdr separate from pcr thus same as other cops)
- NEST4: fixed formula for fertilizers
- NEST5: 3 – assumed to be easy to substitute among land types
- NEST6: 3 – assumed to be easy to substitute among labour types
- NEST7: 3 – assumed to be easy to substitute among labour types

LVSTCK – Livestock production

Applies to: ctl, oap, rmk.
Characteristic: limited substitutability of land with other factors and possibility to substitute feed for land.

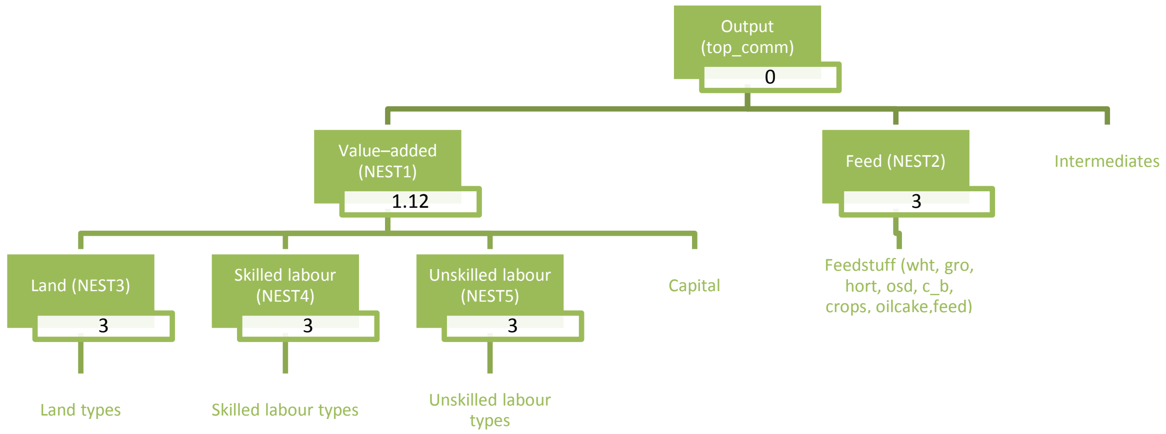


Sources of elasticities:

- Top_comm: GTAP AESUBT
- NEST1: assume limited scope to substitute for land–feed composite
- NEST2: assumed limited scope for substituting feed and land
- NEST3: GTAP ESUBVA
- NEST4: easy to substitute among feedstock
- NEST5: 3 – assumed to be easy to substitute among land types
- NEST6: 3 – assumed to be easy to substitute among labour types
- NEST7: 3 – assumed to be easy to substitute among labour types

FEED – Animal feed production

Applies to: feed.
Characteristic: substitution between different inputs for feed.

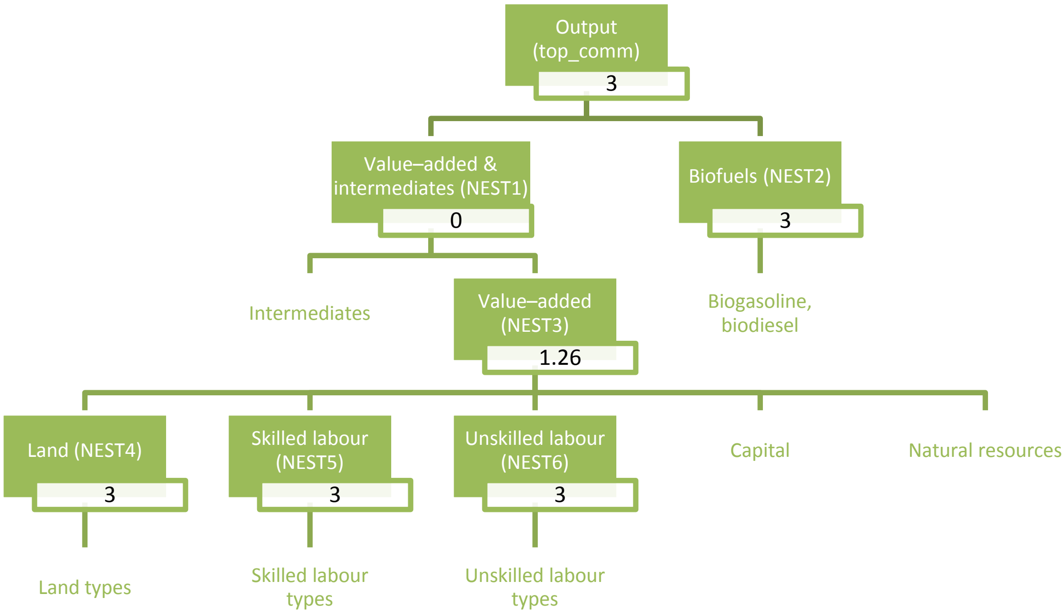


Sources of elasticities:

- Top_comm: GTAP – ESUBT
- NEST1: GTAP – ESUBVA
- NEST2: 3 – assumed to be easy to substitute among feedstuff
- NEST3: 3 – assumed to be easy to substitute among land types
- NEST4: 3 – assumed to be easy to substitute among labour types
- NEST5: 3 – assumed to be easy to substitute among labour types

PETRO – Petrol production and blending

Applies to: petrol.
Characteristic: standard GTAP production structure to which possibility of blending is added at the top.



Sources of elasticities:

- Top_comm: assumed to be easy to blend petro and biofuels
- NEST1: GTAP – ESUBT
- NEST2: 3 – assumed to be easy to blend biofuels
- NEST3: GTAP – ESUBVA
- NEST4: 3 – assumed to be easy to substitute among land types
- NEST5: 3 – assumed to be easy to substitute among labour types
- NEST6: 3 – assumed to be easy to substitute among labour types

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